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**Development and Testing of Theater Analysis Procedures (TAP):
Results from Year 2.**

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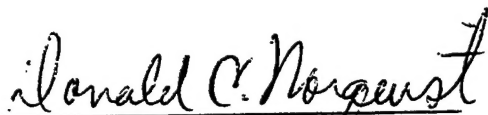
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| 13. ABSTRACT (Maximum 200 words) This report describes the results of the second year of a 3-year project for development of a regional analysis system based on the method of optimal interpolation. The TAP project primary objective is to develop robust analysis procedures to support the tactical user. These analysis procedures provide stable meteorological products for end users. The function of TAP is to combine background (i.e. a priori) information with observations of diverse type, quality, and density to produce analyses of meteorological fields. The status of the system design and prototyping is reviewed. The error statistics databases generated during the first two years, and their implementation in TAP, are described. The results of real-data tests of the prototype system are discussed. | | | | |
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1 Introduction

This report describes the progress made during the second year of the TAP (Theater-scale Analysis Procedure) project.

The TAP project primary objective is to develop robust analysis procedures to support the tactical user. These analysis procedures provide stable meteorological products for end users.

The function of TAP is to use the optimal interpolation technique to combine background (i.e. *a priori*) information with observations of diverse type, quality, and density to produce analyses of meteorological fields. The TAP analysis configurations are optimized to initialize NWP models and to provide input for electro-optical tactical decision aids (EOTDAs).

TAP is modular, and capable of utilizing a variety of background and data sources. This capability allows TAP to adapt to different theater meteorological support systems (TMSSs), run on different platforms and to satisfy different user requirements. TAP is configurable to a range of requirements, from first-in stand-alone capability to full Theater Weather Central (TWC) support.

In the nominal case, background fields for TAP are obtained from short-term forecasts of a global NWP model. This requires established communication links, and a set of representative forecast error statistics (standard deviations and correlations). If timely forecasts are not available, older, longer-range forecasts can be used instead, which requires the use of modified error statistics. Finally, if no usable forecast data exist, a climatological background is used.

During the first year of the project (see Nehrkorn *et al.* 1995 [NehHY95]), a preliminary system design was formulated, reviewed by internal and external reviewers, and partially implemented. To support testing of TAP with real data collection of model output and observational data was begun for selected case studies over the Eastern United States. The climatology data required for the background were collected and processed during the first year. Finally, an extensive bibliography search was conducted to collect and select appropriate statistics for background and observation errors.

During the second year of the project, work has proceeded along several separate fronts:

- System design, prototyping, and unit testing
- Real data system testing
- Development of statistics database

During the second year, the system design developed in the first year of the project has been implemented in an early prototype system. Most of the placeholders of the preliminary end-to-end system at the end of year 1 have been replaced with working code according to the system design. A description of the current system development status is provided in Section 4. Appendix A, which is a copy of preprint article published in the Proceedings of the Eleventh Numerical Weather Prediction conference, contains a brief system description and illustrations of sample analysis output. Detailed descriptions of the system design are provided in separate contract deliverables.

A real-data test of the early prototype system was performed by AWS personnel at Hurlburt Field, Florida. This test used real data captured by AER over the past two years.

A description of the real data tests, including the cases collected so far, the setup and running of the early prototype tests at Hurlburt Field, and a discussion of the results, is provided in Section 2.

The required error statistics database established during the first project year was enhanced with additional data and functional fits. Section 3 contains an updated list of the error statistics database, along with plots and tables of some of the error correlations and standard deviations.

2 Real-Data Tests

2.1 Data Sources and Collection Procedures

Additional real data for system tests have been collected, using the same sources and procedures as during year 1: conventional (surface, ship, buoy, and upper air) data are collected and decoded using the Family of Services database and associated software on the AIMS (Air Force Interactive Meteorological System) system. Direct-readout satellite data are collected from the NOAA and DMSP polar orbiters, using the AIMS ground station equipment. All AIMS data is only collected between latitudes 15° N and 60° N, and longitudes 45° W and 105° W. A variety of gridded model forecast and analysis fields are obtained from the anonymous NCEP ftp-server, in GRIB format.

2.2 Cases Collected

In addition to the two cases collected during year 1 (6-7 March 1995, and the Hurricane Erin case of 2-3 August 1995), two additional case study days have been archived: Hurricane Opal (4-5 October 1995), and 7-8 March 1996. For the sake of completeness, a brief description of all four cases is given here.

2.2.1 6-7 March 1995

Data have been collected for approximately a 24-hour period centered around 12 UTC 6 March 1995. The synoptic situation on that day was characterized by an upper-level short-wave passing through the Northeastern United States and Canada, embedded in a south-westerly upper-level flow. At the surface, this was accompanied by a weak low (central pressure around 1016 hPa) and rain over the Northeastern United States, snow over parts of Quebec and the Canadian Maritimes. This case represents a typical moderate to weak winter/early spring storm over the Northeastern United States. Sample TAP plots from this case are shown in Appendix B.

2.2.2 Erin: 2-3 August 1995

A summertime case was selected to coincide with the landfall of hurricane Erin in Florida. Data were collected for the period 09 UTC 02 August 1995 – 03 UTC 03 August 1995. While most of the East Coast was dominated by high pressure and weak flow at all levels, hurricane Erin made landfall in central Florida (near Vero Beach) at 0545 UTC 2 August.

While over the Caribbean waters, this hurricane had maximum sustained winds of 85 mph, and a central pressure as low as 980 hPa. After landfall, winds dropped to below 70 mph and it was downgraded to Tropical Storm status. At 12 UTC, it was roughly centered over the Florida peninsula, and by 20 UTC its center had moved over the Gulf waters. It subsequently reintensified to hurricane strength and made landfall in the Florida panhandle (in Pensacola Beach) at 1530 UTC 3 August. A secondary feature of interest on this day are the remnants of tropical storm Dean, which were located over parts of Texas, Oklahoma, and Kansas, and which had caused widespread convective rain and flooding.

2.2.3 Opal: 4-5 October

This case coincided with the landfall of Hurricane Opal in the Florida panhandle (right near Hurlburt Field). The time period covered by our archive is 1800 UTC 4 October – 1800 UTC 5 October 1995. Opal made landfall at approximately 2300 UTC 4 October. Opal was a strong hurricane, causing over \$3 billion of damage and over 20 deaths. It thus represents an extreme weather event. Unfortunately, because of the extreme weather conditions, key radiosonde reports are missing for this case at some or all of the levels. Over the Northeast United States, there are weak shortwave features embedded in a generally southwesterly flow. Sample TAP plots from this case are shown in Appendix B.

2.2.4 7-8 March 1996

Data has been collected for 00 UTC 7 March – 12 UTC 8 March 1996 for this case. Over this period, a surface low moved from the Georgia/North Carolina border northeastward to the east of Massachusetts. At the beginning of the time period, the Southeast United States was experiencing strong convective activity with this system, while at later times the Northeastern seaboard was affected with extensive areas of precipitation, falling as rain to the south and snow to the north of a snow/rain boundary located roughly in central Pennsylvania.

2.3 User Interface

While development of a complete user interface and display capability is beyond the scope of the contract (these components are assumed to be available on the host system), these capabilities had to be provided in a united form for testing the early prototype system. For system development and testing, we developed a programming/execution environment which makes use of various tools available to us in the Unix environment (Splus, Gnu Make, Gnu Emacs). Because the test personnel had little or no familiarity with the Unix operating system, the Gnu Emacs editor, or the Splus programming language, the user interface for the real data tests was designed to enable users to run the TAP system from end-to-end with a few simple commands, allowing choices of only a small number of preselected options. Two separate user interfaces were developed: a cshell interface, consisting of a set of cshell scripts to be run from the Unix command prompt, and a HyperText Markup Language (HTML) interface which uses a Web browser (such as Netscape) for user interaction and the display

of the results. Both user interfaces are fully described in the User's Manual produced for the real data tests (see Appendix B).

2.4 TAP Setup

As was mentioned above, only a small subset of all possible configuration options was made available for the real data tests. Two of the four real cases were provided for testing (the March 1995 and Opal case), and two areas of the country were selected as possible analysis areas. Within each area, one of three possible grid configurations could be selected: The outermost, large grid domain covers a region of approximately 1500 km on a side. Centered inside the outer region is the small domain, covering a region of approximately 750 km on a side. Both grids consist of 11 by 11 gridpoints. Finally, the column domain represents the grid column at the center grid point of the small analysis domain. Over the Northeast region, a polar stereographic projection basemap is used (with a reference longitude at 80° W), and the analysis domains are centered over southeast Pennsylvania (see Appendix B). Over the Southeast region, a Mercator projection basemap is used, and analysis domains are centered over Alabama (see Appendix B). The analysis grids were chosen to contain both land areas with dense data coverage and data sparse areas over water. The relatively small grid (11 by 11 gridpoints) was chosen to enable the early prototype code to execute in a timely manner on the workstation used for testing.

Users could choose to perform a surface temperature analysis, or an upper air analysis at a set of preselected pressure levels, for temperature, height, winds, height and winds, or relative humidity. Radiosonde data were used for the upper air analyses, and surface reports for the surface analyses. Either climatology or a 12-hour ETA model forecast could be used for the background field. The resolution of the climatology background (5° longitude by 2.5° latitude) is significantly coarser than even that of the outer analysis grid used in the tests (150 km), whereas the ETA model forecast are available at only slightly coarser resolution (190.5 km at 60° N).

2.5 TAP Installation

We installed the TAP software and data, along with the needed supporting software, on a Sun workstation at Phillips Laboratory (PL) during April and May. During this exercise, we discovered and corrected numerous minor problems with the installation procedure. However, because of compiler incompatibilities between the PL machine and the Splus software (and the Unix installations at AER and CWF), the installation could not be completed at PL. The TAP installation was then repeated on June 4 and 5 at CWF in Hurlburt Field, Florida. With the support of AER computer system staff, and the CWF personnel on-site, both the TAP software and the supporting software (including Splus, Netscape, and Sun compilers) were successfully installed on the Sun workstation at CWF. (A missing memory module on the workstation, however, resulted in somewhat slower execution times.) A written User's Manual (Appendix B) and oral training were provided by AER to enable the test personnel to run and evaluate the early TAP prototype.

2.6 Results of the Prototype Tests

The real-data testing was performed by CWF during June and July, and results (in the form of completed test questionnaires, and summary comments) were returned to PL. These results are summarized below.

A total of eight testers generated between 1 and 3 TAP analyses each. None of the testers had any prior experience with TAP, but most had prior experience with weather analysis and forecasting, and rated their experience with weather displays, and understanding of forecast products, highly (with a score of 3 or higher on a scale from 1 to 5).

The setup and running of TAP presented few serious difficulties for the testers. Five of the eight testers read at least part of the User's Guide, and did not find the instructions difficult. All but one of the testers thought later exercises were easy after the first successful completion: successful completion was obvious, and instructions for the display of the results were clear. Six of the eight testers followed the diagnostic messages, and they all found them understandable. Only one tester experienced an abnormal stop (none of the displays would work). Slightly over one-half of the testers reported some problems (one in setup, one in execution, and three in display); however, all but one tester were able to obtain the expected results from the TAP execution on the first try.

Execution time averaged 5 minutes for the setup, 9 minutes for TAP execution, and 1-2 minutes for display (with the exception of one reported 30 minute time for display). These execution times are generally in line with our own timing tests, and the estimates provided as part of the user interface and User's guide.

The opinion on the realism of the TAP analyses and their usefulness for forecasting was split: 3 testers rated the realism poorly (1 on a scale of 1-5), 2 rated their usefulness for forecasting poorly (1 or 2), but all others gave fair to good marks in both categories (3 or 4). Opinions were similarly divided on whether the data available for the analyses limited their realism and usefulness. A wide range of opinion (from 1 to 5) existed on whether TAP was inflexible (average response = 3.4) or whether it was hard to use (average=3.2).

Of the written comments provided in the questionnaires, and the overall comments by CWF, the most serious criticisms concerned the level of development of TAP: the restriction to predefined analysis regions, which were of small extent and coarse resolution, the restricted flexibility with respect to data sources, and the slow execution speed. The limited possibilities for intercomparison of TAP analyses with observational data and reference analyses was also criticized. Other comments and suggestions for improvements centered on areas outside the scope of the main TAP development effort: desired options for the display of derived quantities (such as vertical velocity, vorticity), different display methods (e.g., wind barbs or streamlines instead of wind vectors), and different units (knots instead of m/s, °F or °C instead of K).

2.7 Discussion

The setup, installation, user interface and documentation for the real data tests of TAP all fulfilled their stated purpose: to enable an end-to-end test of the early prototype system by personnel with no prior experience with TAP. The fact that even those testers that did not read the User's guide successfully completed their exercises on the first try proves the user-

friendliness of the user interface.

Clearly, however, the test results also point out areas of improvement for TAP. Perhaps most important is the need to increase the execution speed (and improve the memory management), to enable TAP to complete analyses on larger analysis grids in a timely manner. This is in fact one of the main system development tasks in the final year of the project. The other main area of improvement is the need to support additional data types, aside from those used in the prototype tests. The real-data tests thus served one of their main objectives: to provide user feedback during the development cycle, and help to focus the development effort on the most important aspects of the analysis system.

The negative ratings with respect to analysis realism and usefulness can, in our view, be explained by the restrictions of the prototype system that are a direct result of the development stage or testing setup, and not representative of the final operational product. In particular, the restrictions in grid size, availability of observational data, and other TAP options all were dictated by the logistical difficulties of testing an early prototype in a quasi-operational environment. In addition, since the only tool available for evaluation of the analyses was their display, their usefulness for initialization of forecast models or input to other weather support algorithms could not be fully assessed.

3 Error Statistics

Inherent in the modular and extensible design of TAP is the separation of the OI algorithm from the underlying observation and error statistics. The latter are specified through tables that can be tailored to the specific needs of the TAP application. An important part of the TAP project is the development of a statistical data base from which appropriate tables can be selected for different backgrounds, geographic areas, and observing systems.

Correlations of both forecast and observational errors are assumed to be separable and horizontally homogeneous. The error covariances are decomposed in the standard OI fashion:

$$C_{xy} = S_x S_y M_{xy} N_{xy}$$

where x and y are observed or forecast variables at observation or analysis locations; C_{xy} is the covariance between the errors of x and y ; S_x is the standard deviation associated with x ; S_y is the standard deviation associated with y ; M_{xy} is the horizontal correlation between the errors of x and y ; and N_{xy} is the vertical correlation between the errors of x and y . In practice, for global analyses the horizontal and vertical correlations may be allowed to vary slowly with vertical and horizontal location. In TAP, they vary geographically as well, but are fixed for a particular case, as described here: the horizontal correlations M_{xy} depend on distance and mean pressure and vertical correlations N_{xy} depend on the two pressures. To be precise, M_{xy} is represented by a set of 1-way tables in terms of horizontal distance, for different mean pressure levels, and N_{xy} is a set of 2-way tables in terms of the two pressures. In any particular case, these tables are interpolated as needed. The tables themselves are external to the analysis procedures. Observations of different type are assumed uncorrelated. Different tables are specified for each different observation and background type. For any analysis domain, appropriate versions of M_{xy} and N_{xy} are used. For some backgrounds and observation types, TAP includes different versions of the correlation tables, appropriate for

the tropics and extratropics or for the continental and maritime situations. A single one of these is chosen when the analysis segment starts. Estimated prediction error standard deviations are also assumed to be constant in the horizontal in the OI development, but are often specified as a function of position. In TAP, background error standard deviations are either obtained as a gridded field (in the case of a climatology background), or specified for different geographical regions. In the latter case, a single set of standard deviations is chosen for the analysis domain.

During the first year of the TAP project, we have conducted an extensive literature survey and assembled a set of appropriate references for the statistics of forecast model errors, observation errors, and deviations from climatology. An inventory of all references used in our literature survey was constructed, containing a description of the type of statistical information available from each reference. This inventory was updated in the second year, and the updated information from this inventory is presented in the following section, organized by the type of statistics, with a brief description of the most relevant references for each type of statistic. Following this overview of error statistics references, the updated statistics selected for the baseline version of TAP are described in more detail.

3.1 Overview of Relevant Error Statistics References

3.1.1 Forecast Model Errors

3.1.1.1 Standard Deviations

[AndGM+86]: Figure of HIRLAM 12-hour 500 hPa height errors.

[BarM92]: Figure of Canadian Meteorological Centre operational model errors of heights and winds as a function of pressure.

[Ben89]: tables of background error standard deviations of height, temperature, relative humidity, and wind used in the MAPS (now called the Rapid Update Cycle, or RUC) isentropic analysis system. The background is NMC's 12-hour NGM forecast.

[BenSM+91, Car91, DevS94]: provide updated values for the statistics in [Ben89] for 3-hour forecasts from the RUC forecast model, for Montgomery potential, pressure, winds, and humidity (condensation pressure).

[Ber79, McPBK+79]: NMC global prediction model errors for temperature, winds, and specific humidity at mandatory pressure levels. Prediction error growth rates for NMC global model.

[DeyM85]: NMC global spectral model 6-hour forecast errors for temperature and winds at 12 mandatory pressure levels, for the extratropics and tropics.

[GoeP93]: NOGAPS global 6-hour forecast errors used in the Navy OI for height, wind, and thickness.

[HolL86, LonH86]: ECMWF global grid point model 6-hour forecast errors for winds, height, and virtual temperature.

[Lor81, LonSU92]: ECMWF forecast errors used in the ECMWF OI for heights, winds, humidity, and thickness, separately for extratropics and tropics.

[MeuRA+90]: Values for the HIRLAM mesoscale forecast model errors for surface temperature and relative humidity.

3.1.1.2 Horizontal Correlations

[AndGM+86]: Functional fits of HIRLAM forecast error correlations for height, MSL pressure, temperature, and relative humidity. Anisotropy included for land/sea contrast.

[Ben89]: Second-order autocorrelation function fits of correlation on isentropic surfaces for NMC's 12-hour NGM forecast.

[Car91, SchC91, DevS94]: provide updated values for the correlations on isentropic surfaces for 3-hour forecasts from the RUC forecast model, for Montgomery potential, pressure, winds, and humidity (condensation pressure).

[DeyM85]: Functional fits for height and humidity error correlations.

[Dim88]: Functional fits for NMC global model error correlations, as used in the NMC RAFS.

[BarM92]: Figure of Canadian Meteorological Centre operational forecast model error correlations for 250 mb winds and 700 mb heights. Sample 2-d and 3-d correlation plots for heights, winds, height-winds.

[GoeP93]: NOGAPS global 6-hour forecast error correlations for heights, transverse and longitudinal winds, and height-wind cross-correlations.

[HolL86, LonH86]: ECMWF global grid point model 6-hour forecast error correlations for longitudinal and transverse winds, height, and wind-height cross-correlations.

[Lor81, LonSU92]: ECMWF forecast error correlations used in the ECMWF OI for heights, longitudinal and transverse winds, height-wind cross-correlations, humidity, and thickness, separately for extratropics and tropics.

[MeuRA+90]: Functional fits for the HIRLAM mesoscale forecast model error correlations for surface temperature, relative humidity, and winds.

[RogDD95]: Functional fits for the NMC Eta model error correlations for height and winds.

3.1.1.3 Vertical Correlations

[AndGM+86]: Table of HIRLAM forecast error correlations for height.

[Ben89]: Vertical correlation matrix for u-component of wind for NMC's 12-hour NGM forecast.

[DeyM85]: Functional fits for height error correlations.

[Dim88]: Functional fits for NMC global model error correlations, as used in the NMC RAFS.

[BarM92]: Canadian Meteorological Centre operational forecast model vertical error correlations for height, wind, and height-wind correlations.

[HolL86, LonH86]: ECMWF global grid point model 6-hour forecast errors vertical correlations for longitudinal and transverse winds, and height.

[LonSU92]: ECMWF forecast error correlations used in the ECMWF OI for heights and longitudinal and transverse winds.

[GoeP93]: NOGAPS global 6-hour forecast error vertical correlations for heights and transverse and longitudinal winds.

[RogDD95]: Functional fits for the NMC Eta model error correlations for height and winds.

3.1.2 Climatology Background Errors

3.1.2.1 Standard Deviations Background error standard deviations for the climatology background are obtained from the climatological variance itself, which is available in gridded form (see Nehrkorn *et al.* 1995 [NehHY95]).

3.1.2.2 Horizontal Correlations

[AndGM+86]: Plots and functional fits of MSL pressure and surface temperature correlations

[Bue71, Bue72]: Plots and functional fits of 500 mb and 200 mb wind and height correlation for summer and winter over Northern Hemisphere continents.

[JulT75, Thi75, Thi76, Thi77, Thi85]: 500 mb height, temperature, and wind correlations and functional fits.

[RamKS73]: 500 mb wind correlations over Indian region.

3.1.2.3 Vertical Correlations No references have been found with tables or functional fits for vertical correlations of climatology background errors. Computation of these statistics is possible from archived datasets, but has been postponed for later phases of the project.

3.1.3 Observation Errors

3.1.3.1 Standard Deviations

[AndGM+86]: Tables of OESDs for height, temperature, relative humidity, and wind for rawinsonde, aircraft winds, SATEM thicknesses, surface pressure and winds, and satellite winds.

[Ben89]: OESDs for height, temperature, relative humidity, and wind for rawinsonde, profiler, aircraft, and surface observations.

[Ber79]: Temperature and wind errors for rawinsonde, aircraft, satellite retrievals, and cloud drift winds.

[Car91]: rawinsonde OESDs for Montgomery potential, pressure, winds, and humidity (condensation pressure) at several isentropic levels.

[DeyM85]: Temperature and wind errors for rawinsonde, aircraft, satellite retrievals, and cloud drift winds.

[GoeP93]: Temperature, height, thickness, and wind errors for rawinsonde, aircraft, satellite retrievals, cloud drift winds, and surface observations.

[LonSU92]: Temperature, height, thickness, wind, and humidity errors for rawinsonde, aircraft, satellite retrievals, and cloud drift winds, surface observations, drifting buoys, and pilot balloons.

[Lor81]: Temperature, height, thickness, and wind errors for rawinsonde and aircraft observations.

3.1.3.2 Horizontal Correlations

[AndGM+86]: Functional fit for satellite derived thicknesses.

[DeyM85]: horizontal correlations of satellite retrieved thickness errors.

[LonSU92]: horizontal correlations of satellite retrieved thickness errors.

3.1.3.3 Vertical Correlations

[Ber79]: Rawinsonde error vertical correlations for winds and geopotential. Satellite height error correlations.

[HolL86, LonH86]: Rawinsonde error vertical correlations for winds, geopotential, and thickness.

[LonSU92]: Rawinsonde error vertical correlations for geopotential, satellite retrieval thickness error vertical correlation.

[GoeP93]: Radiosonde height error vertical correlation.

3.2 TAP Baseline Error Statistics References

The error statistics for the baseline version of TAP rely most heavily on the statistics used in NOGAPS (Goerss and Phoebus, 1993 [GoeP93]). The primary reason is that, at the beginning of this project, the most likely scenario for a TAP implementation was for global forecast model background fields obtained from the Navy NOGAPS model. The NOGAPS model error statistics were thus most relevant to TAP. Furthermore, the Navy NOGAPS system is a state-of-the-art operational system with recent and fairly complete and accessible documentation. These statistics have been supplemented where needed with information from other sources from the above list, in most cases from the ECMWF documentation found in Lönnberg *et al.* (1992 [LonSU92]). Elements for which no source has yet been selected have been marked by "TBD". Where no entry for correlations exists, autocorrelations are assumed to be zero except at zero separation, and crosscorrelations are assumed to be zero.

3.2.1 Forecast Model Errors

3.2.1.1 Standard Deviations These standard deviations have all been derived from comparisons with radiosonde data over well-sampled regions. As a possible enhancement, these values could be inflated by an appropriate error growth rate over data-sparse regions.

height: [GoeP93, Tables on p. 41]

temperature: Values computed from height error covariances

thickness: computed from height error covariances

winds: [GoeP93, Tables on p. 41]

relative humidity: [LonSU92, p.3.5]

3.2.1.2 Horizontal Correlations

height: [GoeP93, eq. 30, p.12-13]

temperature: use values for height from [GoeP93, eq. 30, p.12-13]

thickness: computed from height error covariances

winds: compute from height correlations, as in [GoeP93, eq. 31-41, p.13-14]

height-winds crosscorrelations: compute from height correlations, as in [GoeP93, eq. 31-41, p.13-14]

relative humidity: [LonSU92, p. 3.5]

3.2.1.3 Vertical Correlations

height: [GoeP93, p.18]

thickness: computed from height error covariances

temperature: computed from height error covariances

winds: use vertical correlation function for height

3.2.2 Climatology Model Errors

3.2.2.1 Standard Deviations Background error standard deviations for the climatology background are obtained from the climatological variance itself, which is available in gridded form (see Nehr Korn *et al.* 1995 [NehHY95])

3.2.2.2 Horizontal Correlations

height: [JulT75, Tables 1 and 2, function R2.1]

temperature: use values for height from [JulT75]

thickness: computed from height error covariances

winds: compute from height correlations, as in [GoeP93, eq. 31-41, p.13-14]

height-winds crosscorrelations: compute from height correlations, as in [GoeP93, eq. 31-41, p.13-14]

relative humidity: use values from [LonSU92, p. 3.5]

3.2.2.3 Vertical Correlations

height: use the same functional form as [GoeP93, p.18] with an adjusted vertical length scale ($= 6500m$)

thickness: computed from height error covariances

temperature: computed from height error covariances

winds: use vertical correlation function for height

3.2.3 Observation Errors

The observation errors in these references have not been adjusted for the representational error (*i.e.*, the representational error has not been separated from the instrument error). This is left as a future enhancement to the statistical database.

3.2.3.1 Standard Deviations

rawinsonde: height: [GoeP93, Tables on p.41]

temperature: a nominal value of 0.5 K is used

winds: [GoeP93, Tables on p.41]

relative humidity: [LonSU92, p.3.1]

aircraft winds: [GoeP93, Tables on p.41]

satellite retrievals: thickness: [GoeP93, Tables on p.41]

temperature: [LonSU92, p.2.36]

relative humidity: [LonSU92, p.3.4]

cloud drift winds: [GoeP93, Tables on p.41]

surface observations: height: [GoeP93, Tables on p.41]

winds: [GoeP93, Tables on p.41]

temperature: a nominal value of 0.5 K is used

relative humidity: [LonSU92, p.3.1-3.3]

3.2.3.2 Horizontal Correlations

satellite thickness: [LonSU92, p. 2.37]

cloud drift wind: TBD

3.2.3.3 Vertical Correlations

rawinsonde height: [LonSU92, p. 2.38]

satellite thickness: The values given in [LonSU92, p. 2.39] were negligibly small. The TAP baseline version uses zero vertical correlations.

3.3 TAP Baseline Error Statistics Data

In this section, we describe the error statistics models of the TAP baseline error statistics references, to the extent that they have been implemented in TAP.

3.3.1 Standard Deviations

Summary plots of the error standard deviations are shown in Figure 1 for height errors of the forecast first guess and Raob reports, and thickness errors of clear and cloudy satellite retrievals. Figure 2 contains the temperature errors of the forecast and Raobs, Figure 3 the wind errors of the forecast, Raobs/Pibals, aircraft reports, and cloud-drift winds. Observation errors that do not depend on altitude are given in Table 1.

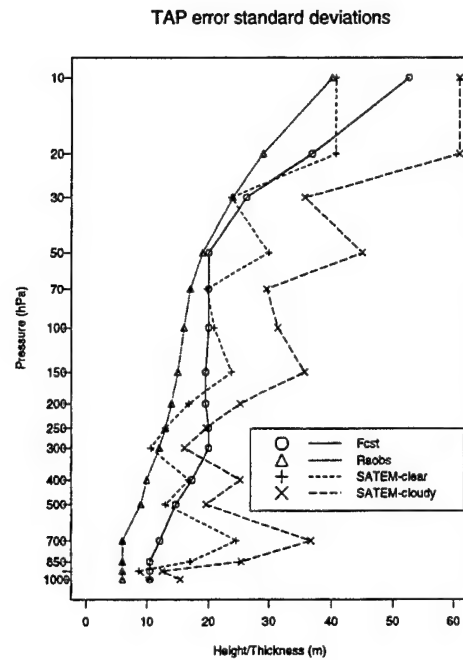


Figure 1: Height and thickness (for SATEMs) error standard deviations used in TAP.

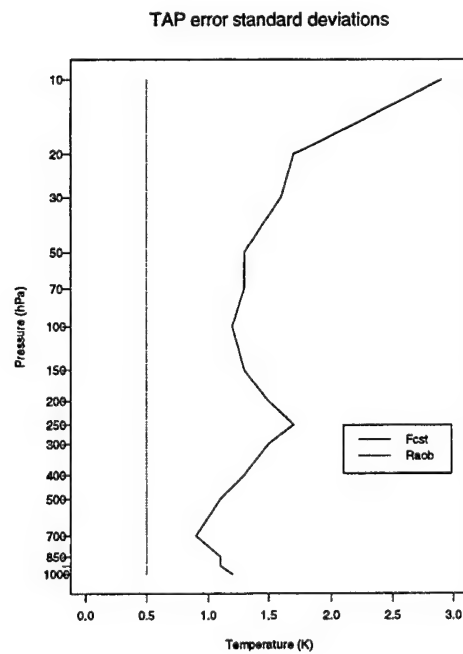


Figure 2: Temperature error standard deviations used in TAP.

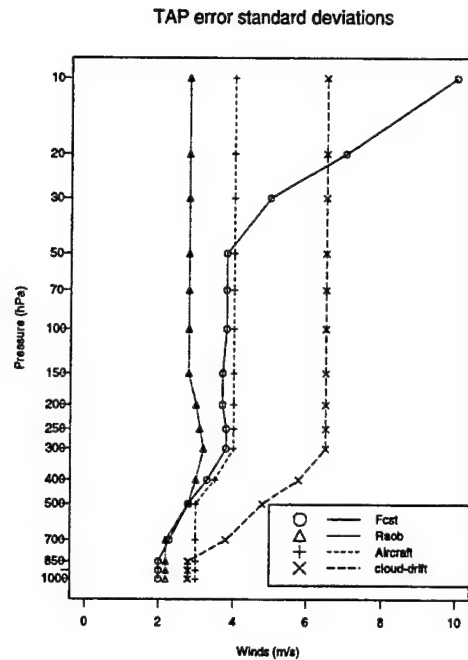


Figure 3: Wind error standard deviations used in TAP.

Table 1: Observation errors used in TAP. SATEM indicates satellite retrievals, Surface all surface land, ship, and buoy observations, and Paobs manually bogused observations of tropical storms based on satellite imagery.

| Type | Height m | Winds m/s | Temperature K | Relative Humidity % |
|---------|-------------|--------------|------------------|------------------------|
| SATEM | | | | 15 |
| Raob | | | | 15 |
| Surface | 6 | 2.2 | 0.5 | |
| SSM/I | | 2.2 | | |
| Paobs | 24.1 | | | |

3.3.2 Horizontal correlations

The functional fit of the height-height error correlations for the NOGAPS forecast model is given by the following modified second-order autoregressive (SOAR) function:

$$\rho_{zz}(r) = 1 - c_2(1 + c_1)\exp(-c_1r) ,$$

where r is the great circle separation distance, and c_1 and c_2 are constants ($c_1 = 2.6 \cdot 10^{-3} km^{-1}$ and $c_2 = 0.9$). The function is shown in Figure 4. The resulting contour plot of correlation values is shown in Figure 5 over a map background.

In the present version of TAP, the height-height correlation function is also used for the computation of mass-wind and wind-wind correlations. Only a brief outline of the procedure is given here – the mathematical details can be found in the Software Requirements Specification and Software Design Document, which are provided as separate contract deliverables. All correlations involving wind components are computed in terms of the natural coordinate system (longitudinal \tilde{u} and transverse \tilde{v}) components, and converted to the local (east and north) coordinate system as needed. Using assumptions of isotropy and homogeneity, the wind correlations can then be related to those of streamfunction (ψ) and velocity potential (χ). TAP also employs the common assumption that $\rho_{\psi\psi} = \rho_{\chi\chi}$ and $\rho_{\psi\chi} = 0$. For the baseline set of error statistics, the horizontal structure functions of streamfunction and velocity function are not specified independently, but instead set equal to the height-height autocorrelation function. If we define a length scale L from

$$L^2 = \frac{-2\rho_{zz}(r=0)}{\nabla^2\rho_z(r=0)} = \frac{-2\rho_{zz}(r=0)}{(\frac{1}{r}\frac{d}{dr} + \frac{d^2}{dr^2})\rho_{zz}(r=0)} ,$$

and rescaled first and second derivatives of the horizontal structure function as

$$\begin{aligned} f &= -\frac{L^2}{r} \frac{d}{dr} \rho_{zz}, \\ g &= -L^2 \frac{d^2}{dr^2} \rho_{zz}, \end{aligned}$$

we can write the wind-wind correlations as follows:

$$\begin{aligned} \rho_{\tilde{u}\tilde{u}} &= (1 - \nu^2)N_{\psi\psi}f + \nu^2N_{\chi\chi}g, \\ \rho_{\tilde{v}\tilde{v}} &= (1 - \nu^2)N_{\psi\psi}g + \nu^2N_{\chi\chi}f, \\ \rho_{\tilde{v}\tilde{u}} &= \rho_{\tilde{u}\tilde{v}} = 0, \end{aligned}$$

where $N_{\psi\psi}$ and $N_{\chi\chi}$ are the vertical correlation functions for streamfunction and velocity potential, and the parameter ν^2 can be specified to control the partitioning between rotational and divergent kinetic energy ($0 \leq \nu^2 \leq 1$). As can be seen, the wind autocorrelations are linear combinations of the functions f and g when $N_{\psi\psi} = N_{\chi\chi}$. If the errors are assumed to be nondivergent ($\nu^2 = 0$), f and g are the autocorrelation functions of the longitudinal and transverse components, respectively. These functions are also shown in Figure 4.

Finally, height-wind correlations are obtained from the relation

$$\rho_{z\tilde{v}} = L\sqrt{1 - \nu^2} \frac{d}{dr} \rho_{z\psi} ,$$

where it was assumed that $\rho_{zx} = 0$, from which it follows that $\rho_{z\bar{u}} = 0$. In the baseline version of the TAP error statistics, height and streamfunction are geostrophically coupled with an adjustable parameter μ ($|\mu| \leq 1$): $\rho_{z\psi} = \mu\rho_{zz}$.

An example of the resulting horizontal correlation functions in terms of the local (east/north) coordinate system is given in Figure 5. For those plots, parameters appropriate for a tropical location were chosen ($\mu = 0.5$ and $\nu^2 = 0.1$) – the map background is only provided to give a sense of the spatial scale.

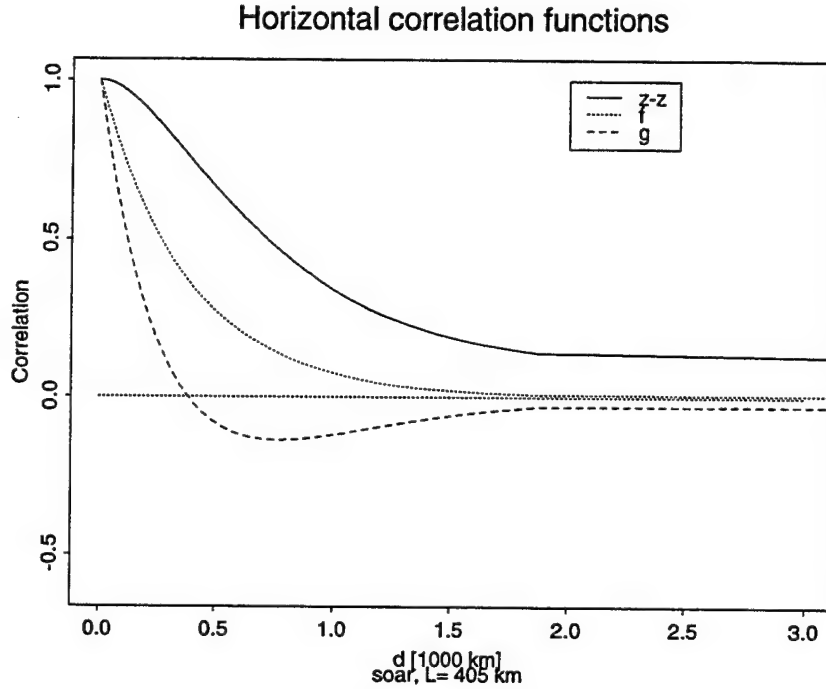


Figure 4: Horizontal height error correlation functions for NOGAPS (see text). The horizontal axis is separation distance in units of 1000 km

For the climatology background, the horizontal error correlation function is given by

$$\rho_{zz}(r) = \frac{\alpha \cos(\omega r) + 1 - \alpha}{\sqrt{1 + \lambda^2 r^2}},$$

with $\alpha = 0.738$, $\omega = 1.38 \cdot 10^{-3} km^{-1}$, and $\lambda = 0.848 \cdot 10^{-3} km^{-1}$. The function is shown in Figure 6, along with its rescaled first and second derivatives. The resulting horizontal maps of height-height, wind-wind, and height-wind correlations are shown in Figure 7.

Finally, the relative humidity error correlations, for NOGAPS and climatology backgrounds, are modeled by a negative squared exponential (NSE) function:

$$\rho(r) = e^{-0.5(r/L)^2},$$

with $L = 300 km$. This function is shown in Figure 8.

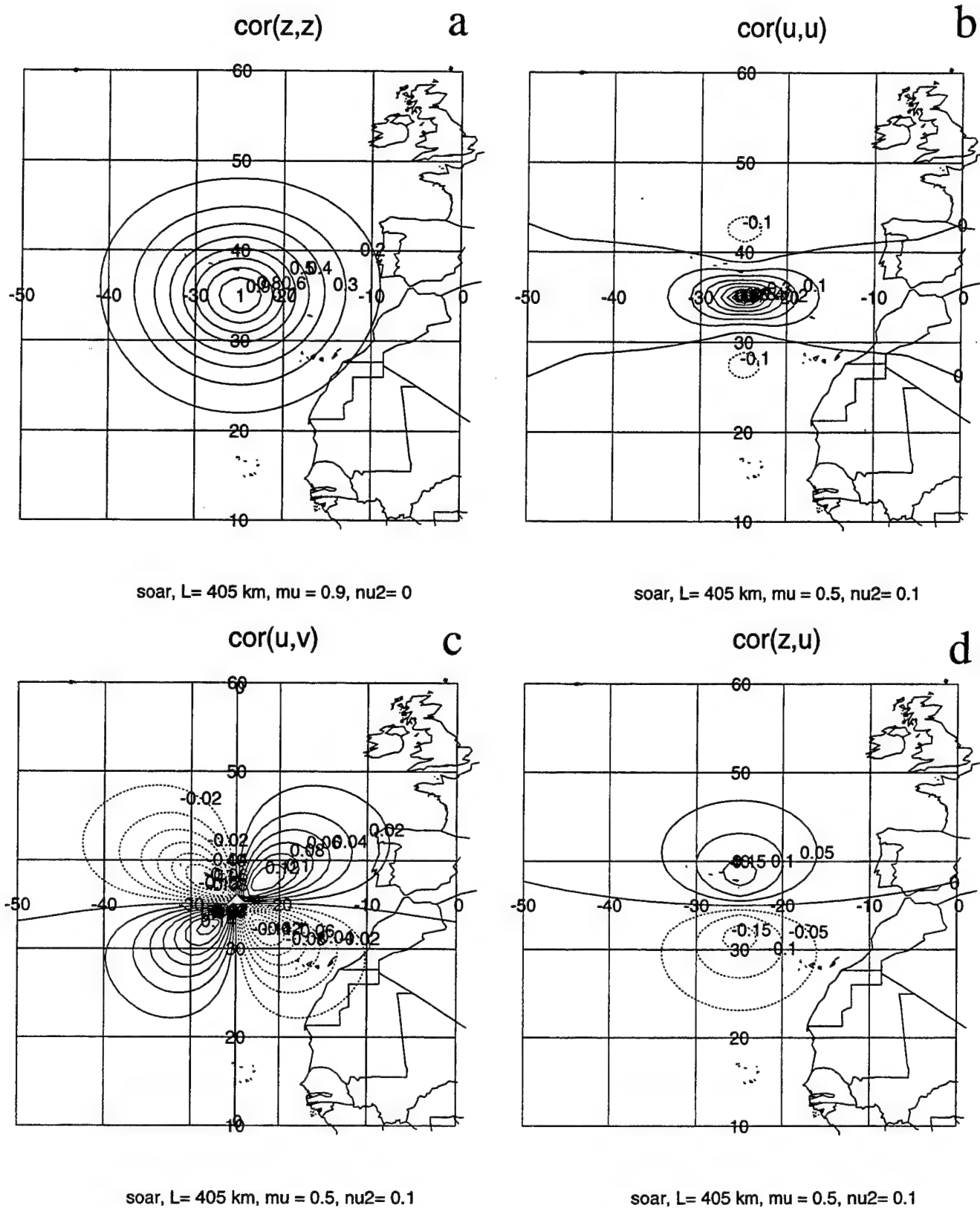


Figure 5: Horizontal maps of NOGAPS forecast error correlations with a single observation at the grid center: (a) height-height; (b) zonal wind - zonal wind; (c) zonal wind - meridional wind; (d) height - zonal wind.

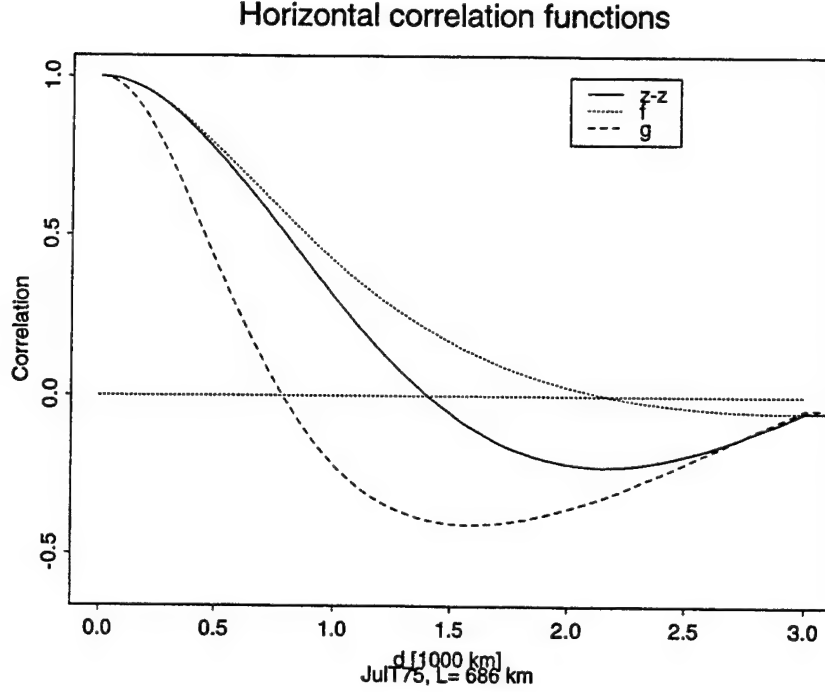


Figure 6: Horizontal height error correlation functions for climatology.

3.3.3 Vertical correlations

For the baseline version of the TAP error statistics, the vertical correlation functions of the velocity potential and streamfunction autocorrelation, and the cross-correlation of height with the transverse wind component, are set equal to the height-height autocorrelation function. The functional form given in Goerss and Phoebus (1993 [GoeP93]) is

$$N_{zz}(z_1, z_2) = \exp\left(-\left(\frac{|z_1 - z_2|}{dz}\right)^b\right),$$

where z_1 and z_2 are the height of the two observations, b and dz are adjustable constants ($b = 1.8$, $dz = 3600$ m). As used in TAP, the natural logarithm of pressure is used instead of height, and the length scale dz is replaced by the equivalent log-pressure scale obtained from the hydrostatic relationship

$$|d \ln p| = \frac{g}{RT} |dz|,$$

where g is the acceleration of gravity, R the gas constant for air, and T a reference temperature ($T = 250$ K). The functional form for N_{zz} is evaluated for all possible combinations of the standard pressure levels and stored in tabular form. Figure 9 shows the resulting correlations for an observation at 500 hPa, both from the continuous functional form, and as evaluated by interpolation from the table.

The tabular data of N_{zz} are further used to derive the vertical correlation table for temperature. For any two variables that are related linearly, as in

$$T = Mz,$$

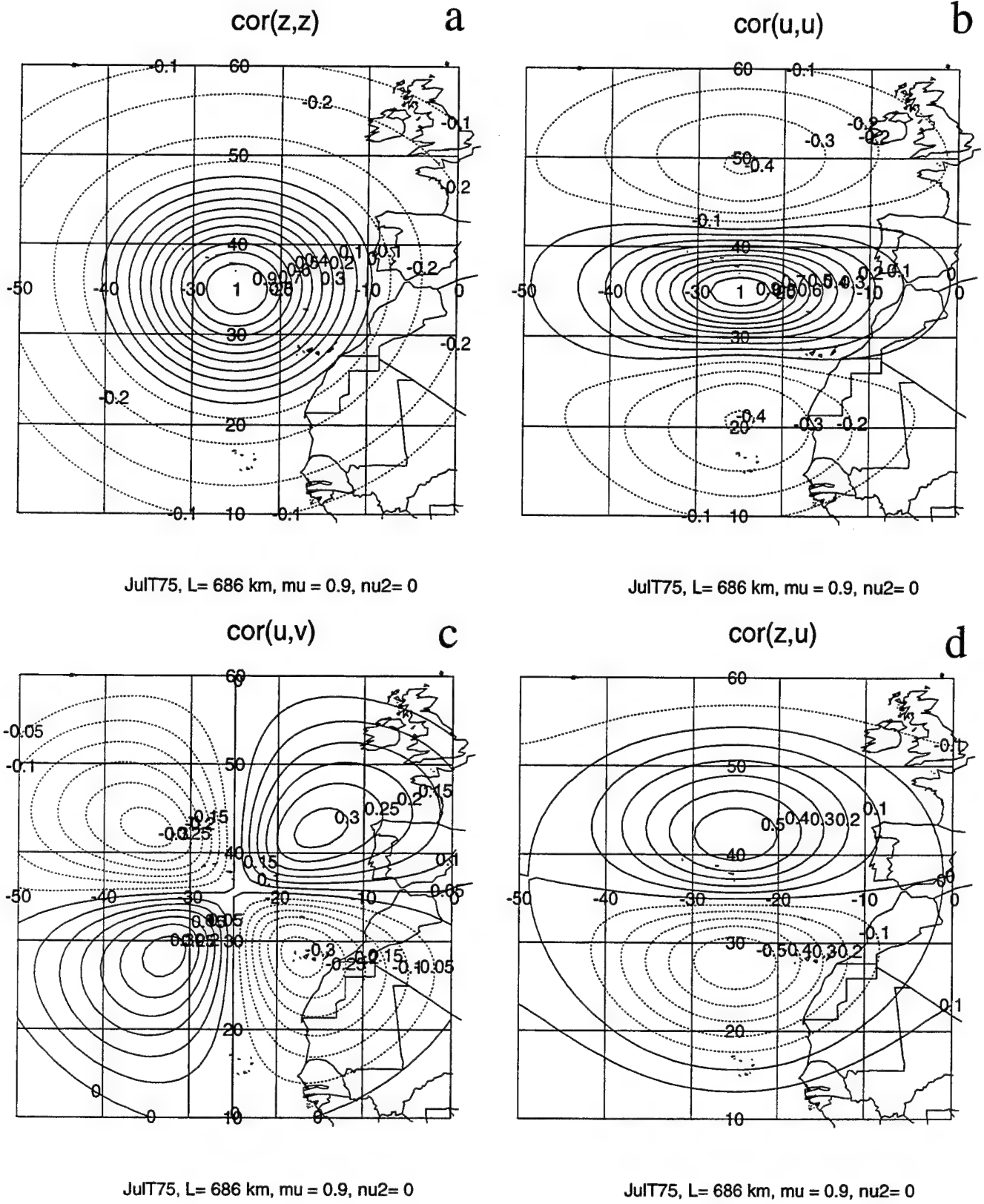


Figure 7: Horizontal maps of climatology error correlations with a single observation at the grid center: (a) height-height; (b) zonal wind - zonal wind; (c) zonal wind - meridional wind; (d) height - zonal wind.

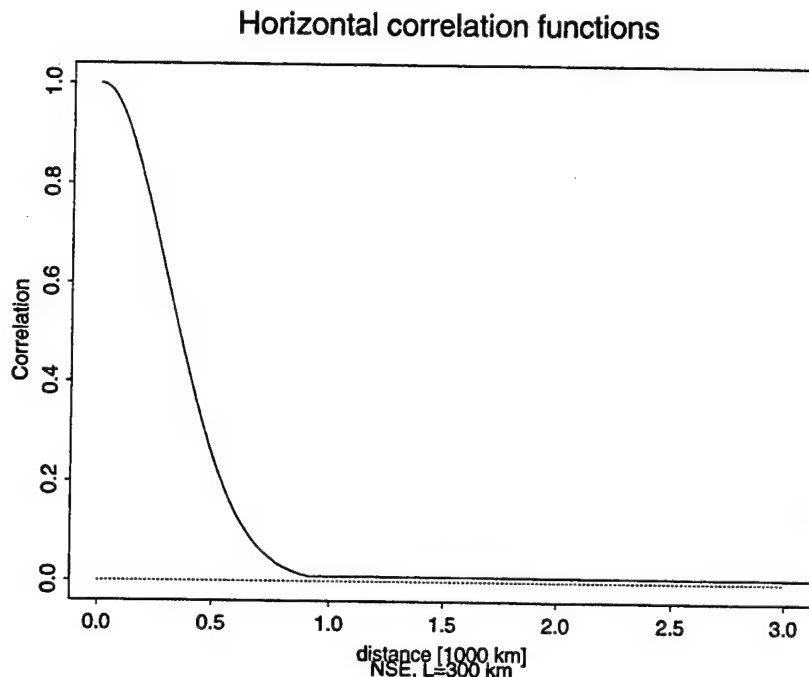


Figure 8: Horizontal relative humidity error correlation functions for NOGAPS and climatology.

where T and z are column vectors containing temperature and height values at the N pressure levels, and M is an N by N matrix, the covariance matrix of T ($S_T = \langle TT^* \rangle$) can be computed as follows:

$$S_T = M \langle zz^* \rangle M^* = M S_z M^*,$$

where M^* indicates the matrix transpose. The matrix M is obtained from the application of the hydrostatic relationship. In these computations, the tabulated values of the height standard deviations are used to convert N_{zz} to S_z . The resulting values of N_{TT} for a temperature observation at 500 hPa are also shown in Figure 9.

For climatology backgrounds, no published sources for vertical correlation functions have been found. Computation from available data sources has not been performed to this date because of problems of assembling and processing the required data bases. A standard radiosonde dataset we had planned on using for this purpose (the so-called TIGR dataset used in connection with satellite retrievals) turned out to be unsuitable because it did not contain date/location information for the individual profiles. Because it was then impossible to separate contributions from geographical versus time variations to the covariances, the vertical correlations of the deviations from the overall mean profile are unrealistically large when applied to a gridded climatological first-guess field. Acquisition and quality control of other archived radiosonde data was postponed for later phases of the project. Instead, we generated vertical correlations from the same functional form as for the NOGAPS data, but adjusted the function parameters for somewhat broader correlation functions ($dz = 6500$ m). The resulting height-height and temperature-temperature correlations for a 500 hPa observation are shown in Figure 10.

The only vertical correlation functions of observation errors that have been added to

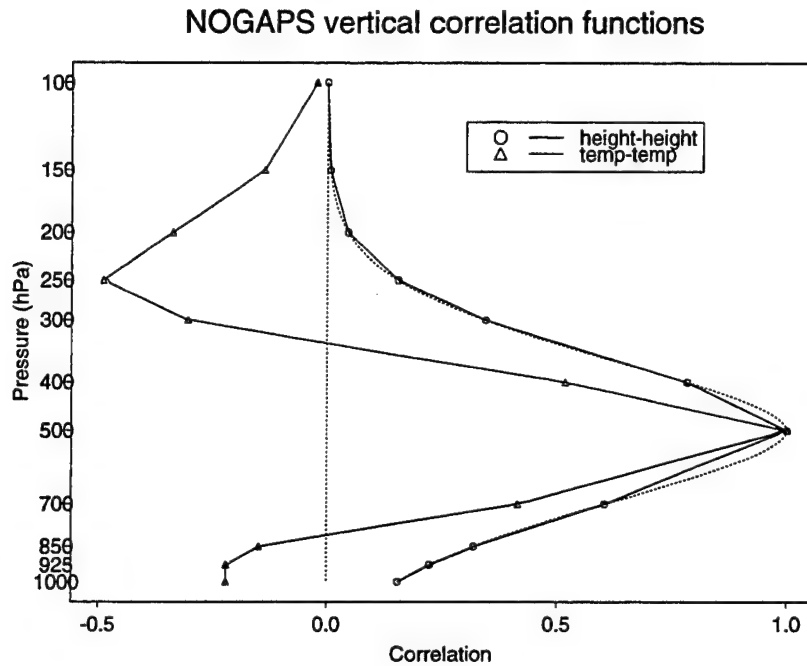


Figure 9: Vertical error correlation functions for NOGAPS for an observation at 500 hPa . Values from table shown as symbols. At intermediate pressures, plotted values are interpolated from the table (solid lines) or computed from continuous functional form (dashed line)

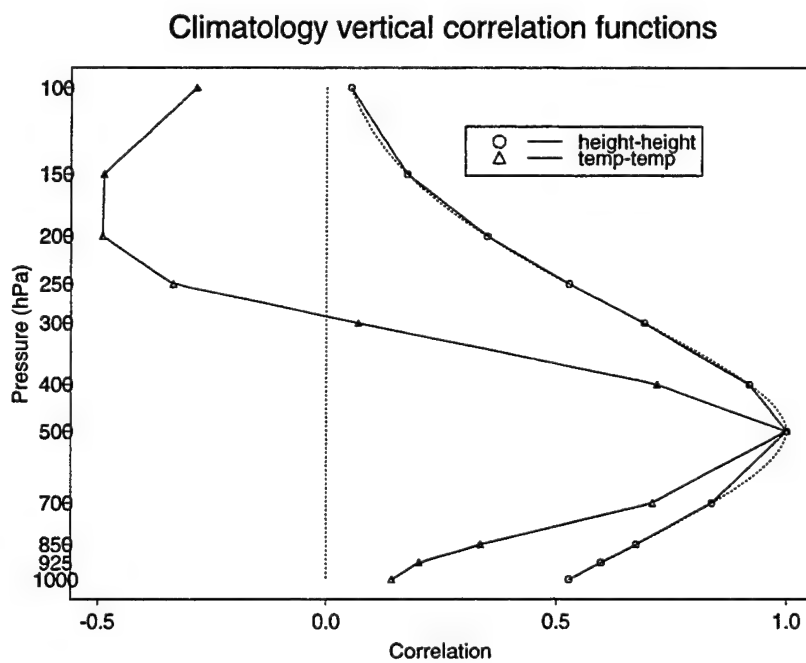


Figure 10: Vertical error correlation functions for climatology for an observation at 500 hPa . Values from table shown as symbols. At intermediate pressures, plotted values are interpolated from the table.

TAP are those of radiosonde heights. They are taken directly from Lönnerberg *et al.* (1992 [LonSU92]). These values are shown in Table 2.

Table 2: Vertical correlation ($\times 1000$) of radiosonde height observation errors used in TAP.

| | 1000 | 850 | 700 | 500 | 400 | 300 | 250 | 200 | 150 | 100 | 70 | 50 | 30 | 20 | 10 |
|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 1000 | 1000 | 716 | 276 | 29 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 850 | 716 | 1000 | 733 | 183 | 55 | 9 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 700 | 276 | 733 | 1000 | 573 | 268 | 77 | 31 | 10 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 500 | 29 | 183 | 573 | 1000 | 851 | 480 | 288 | 138 | 49 | 11 | 3 | 1 | 0 | 0 | 0 |
| 400 | 5 | 55 | 268 | 851 | 1000 | 814 | 601 | 364 | 167 | 51 | 19 | 7 | 1 | 0 | 0 |
| 300 | 1 | 9 | 77 | 480 | 814 | 1000 | 935 | 738 | 458 | 200 | 93 | 44 | 11 | 2 | 0 |
| 250 | 0 | 3 | 31 | 288 | 601 | 935 | 1000 | 919 | 678 | 361 | 194 | 104 | 31 | 7 | 0 |
| 200 | 0 | 1 | 10 | 138 | 364 | 738 | 919 | 1000 | 895 | 597 | 375 | 229 | 84 | 24 | 2 |
| 150 | 0 | 0 | 2 | 49 | 167 | 458 | 678 | 895 | 1000 | 861 | 649 | 460 | 214 | 78 | 9 |
| 100 | 0 | 0 | 0 | 11 | 51 | 200 | 361 | 597 | 861 | 1000 | 929 | 782 | 480 | 230 | 42 |
| 70 | 0 | 0 | 0 | 3 | 19 | 93 | 194 | 375 | 649 | 929 | 1000 | 951 | 710 | 412 | 103 |
| 50 | 0 | 0 | 0 | 1 | 7 | 44 | 104 | 229 | 460 | 782 | 951 | 1000 | 878 | 598 | 192 |
| 30 | 0 | 0 | 0 | 0 | 1 | 11 | 31 | 84 | 214 | 480 | 710 | 878 | 1000 | 881 | 426 |
| 20 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 24 | 78 | 230 | 412 | 598 | 881 | 1000 | 725 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 9 | 42 | 103 | 192 | 426 | 725 | 1000 |

4 Prototype System Development

The algorithm prototyping during the first year of the TAP project had resulted in a preliminary end-to-end analysis system, which was limited to a scalar analysis, and with parts of the full system design either replaced by Splus library functions or omitted. During the second year, a large number of the missing components have been coded, unit tested, integrated, and system tested.

We note that TAP is designed to be hosted within a work station based meteorological display and analysis system. Since this system is not fully defined, TAP formally begins and ends with the interface described by the COF data structure. Therefore our development plan calls for only limited preprocessor and postprocessor capabilities. Graphical and user interface facilities are likewise limited and have been developed solely for the purpose of testing TAP and using COTS where possible. Nevertheless substantial progress has been made in all these areas as well as in the core TAP algorithms and statistics data bases. Section 3 of this report describes the current TAP statistics data bases and calculations involving the statistical quantities.

As detailed in the Software Requirements Specifications (srs), the preprocessing segment has several main functions. The first is the translation of each specialized data format into the Comprehensive Observation Format (COF). This is the format used internally by TAP. Modules have been written to ingest and reformat the following data types: surface observations by synoptic, airport, and ship and buoy reporting sites, in the format provided by the AIMS system; radiosonde reports, also in the AIMS format. For the early prototype system, some manual reformatting of the AIMS data is required. The second generates the output analysis COF file. This sets up the empty COF structure with the proper latitude, longitude, vertical coordinate and variable type for the analysis. This module has been

implemented with the capability to generate an analysis cof from a specified (arbitrary) arrangement of analysis longitude and latitude points, or from a grid on a supported map projection (using a GRIB style grid definition). At present, analysis levels are assumed to be isobaric levels. The third interpolates the background and, if it is present in the same format, the background error standard deviations for each datum in a COF file. Modules have been written for the ingest of the TAP climatology data base, and for forecast background fields in GRIB format. The interpolation routines are independent of the input format. A current restriction of the system is that the background field is assumed to be on isobaric surfaces. The fourth transforms variables into new variables more suitable for the OI. For example, units are changed to the SI units used throughout TAP, and winds are rotated from the model grid to the East/North coordinate system. Fifth the data preprocessing provides for each datum an expected standard deviation, if these are not already determined by the COF translation from the data base. Background error standard deviations and error standard deviations due to representativeness and timeliness for both observed and background values are added at this point. The preprocessor accesses *a priori* statistics specified in tabular form for these purposes. This function has been implemented with the exception of timeliness errors (backgrounds and observations are all assumed to be timely), but including the derivation of background thickness errors from the height error standard deviations and their vertical correlations. The sixth and seventh data preprocessing functions are QC functions. These were not implemented by the end of the second year. Finally, the preprocessor includes utility functions to merge, sort and select the COF data, as needed, so as to produce a single COF file containing all the data to be used by an analysis. These have been fully implemented.

There are four postprocessing functions needed to produce the desired output data sets from TAP. First, the analysis is transformed into new variables as needed. This is presently implemented for the rotation of the wind components. Second, the analysis values are optionally smoothed horizontally. Third, the QC information from the analysis is reformatted to be passed back to the TMSS data base. These two functions have not been implemented in the prototype. Fourth, the analysis is regridded. That is, the analyzed fields are reformatted into a more grid-like format. This is presently implemented by using the same GRIB-style grid definition used for the creation of the analysis cof in the preprocessor, with the same restriction that analysis levels are assumed to be isobaric.

Graphics capabilities implemented for the purpose of system diagnostics and the testing at CWF include routines for horizontal contour and shade plots and vector displays of gridded fields, including the capability to overlay map backgrounds; facilities for plotting locations and values or vectors of selected headers or bodies of the analysis or data cof. Top level routines have also been written that combine these facilities for a series of standard plots, using reasonable defaults for a variety of graphical parameters (such as the number of contour levels, the number of digits to include on text displays, etc.).

With regard to the TAP analysis algorithms, for the volume method, we have implemented matrix solvers using the LAPACK library. Code was added to perform a two-dimensional analysis of surface variables (so far this capability has only been tested for temperature). For the multivariate analysis of winds and height, code was added to virtually all parts of the system: to the preprocessing and postprocessing segments, for rotation of wind components from grid-relative to earth-relative coordinate systems; to the correlation

computations, for the computation of wind-wind and mass-wind correlations; to the plotting routines, for plotting of wind data.

Timing and memory diagnostics have been added to the prototype system. The top-level routines were streamlined to accomodate different options for the different analysis schemes, and to improve memory management. Aside from a limited set of routines written in Fortran (the LAPACK routines for the solution of the analysis equations, and the routines for the transformation from grid coordinates to latitude-longitude coordinates), all algorithms have been implemented in Splus. This allowed rapid prototyping and testing of the algorithms, but it imposed some limitations on the feasible problem size because of high demands on computer resources (mainly memory, but also CPU time). For the tests at CWF, these limitations were accomodated by a proper selection of "canned" cases available for testing.

In preparation for the testing at CWF, a graphical (html based) and cshell user interface have been developed, tested, and documented. These are documented in detail in Appendix B. This user interface was limited in a number of ways to allow testing of the early prototype: the range of allowable options was restricted to one default set of adjustable parameters, and a limited number of choices for data sources, analysis levels, and analysis variables. Graphical displays were limited to a set of standard plots, produced as postscript files and displayed using a postscript viewer.

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A Development of a Small-Scale, Relocatable Optimum Interpolation Data Analysis System

Conference paper contained in the Preprints of the 11th Conference on Numerical Weather Prediction of the American Meteorological Society, held in Norfolk, Virginia, August 1996.

DEVELOPMENT OF A SMALL-SCALE, RELOCATABLE OPTIMUM INTERPOLATION DATA ANALYSIS SYSTEM

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1 INTRODUCTION

A prototype optimum interpolation (OI) analysis system is being developed to provide detailed atmospheric analyses under a variety of conditions. The analysis system is designed to be part of a meteorological workstation with its own system for receipt, storage, and display of meteorological data. Its output can be used for display or initialization of locally run mesoscale models. The system is designed to be flexible to adapt to different user requirements: it can generate two or three-dimensional, univariate or multivariate (mass-wind) analyses; it can produce analyses on regular grids using a number of different map projections, or on arbitrarily spaced analysis points; it is able to utilize different background (or first guess) fields, ranging from mesoscale or large-scale model forecasts to climatological background fields; it can be configured to operate over any region of the globe; it can accept a wide variety of observations. Aspects of the system design are reviewed in the next section, results from a preliminary prototype version of the analysis system are shown in section 3, and future plans are discussed in section 4.

2 SYSTEM DESIGN

The analysis system consists of a preprocessor component, analysis component, and postprocessor component.

The preprocessor is responsible for ingest and reformatting of the background, observation, and auxiliary data. This includes preliminary quality control checks of the observations: a check on the magnitude of the difference from the background, and a median filter "buddy check" for some densely spaced data (particularly satellite-derived observations). If

needed, the background fields are also interpolated to the analysis grid as part of the preprocessor, and input variables are transformed to those used within the analysis (e.g., dew point to specific humidity, grid-relative wind components to east-west components).

The postprocessor performs similar functions, in reverse: variable conversions from analysis to display variables, regridding from analysis to display grids, reformatting from internal to database formats, and storage of the analysis output in the workstation database.

In the analysis component the background and observations are combined using the standard OI formulation (Lorenc, 1981). Analysis values (A) at each of the grid points are obtained by a linear combination of the first guess (P) and a weighted sum of the surrounding observation increments ($O - P$):

$$A = P + w^T(O - P),$$

where the weights w are determined from the normal equation

$$Mw = h.$$

Here M is the symmetric positive definite matrix with elements given by

$$m_{ij} = \langle \pi_i \pi_j \rangle + \epsilon_i^o \langle \beta_i \beta_j \rangle \epsilon_j^o,$$

and the elements of h are given by

$$h_i = \langle \pi_i \pi_k \rangle.$$

In these equations, the terms $\langle \pi \pi \rangle$ are the background error correlations and the terms $\langle \beta \beta \rangle$ are the observational error correlations, which are multiplied by the ratio (ϵ^o) of observation to background error standard deviations. Correlations between background and observational errors are assumed to be zero.

At present, the analysis equations are solved using the volume method, in which a single matrix equation is inverted for all analysis grid points within a

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specified volume. An alternative method will be implemented, in which the normal equations are solved point by point using a small subset of observations around each analysis point. This method has the advantage of faster execution times and a straightforward implementation of the OI buddy check procedure, but the resulting analyses may be noisy because of differences in data selection of neighboring gridpoints.

The background and observation error covariances are computed from the corresponding standard deviations and correlations. Correlations are modeled as separable function, i.e. as the product of vertical and horizontal (along pressure surfaces) correlations. To accommodate the desired flexibility of the system with respect to geographic location, the resolution of the input and output fields, and the type of background and observation data, the specification of the required error statistics is separated from the rest of the system design. Observation and background error standard deviations are stored in tables. Horizontal and vertical correlation functions for background and observation errors are also stored in tabular form, with an option to generate them from functional fits to empirical data. Correlations involving wind components are computed using the natural coordinate system of longitudinal and transverse wind components, after Daley (1991).

An example plot of horizontal height-height error correlations is shown in Fig. 1 for the second-order autoregressive function (SOAR) (Goerss and Pheobus, 1993) used for global forecast model background fields. The curves labeled "f" and "g" refer to the (rescaled) first and second derivative of the correlation function (labeled "z-z"). The autocorrelations of the transverse and longitudinal wind components are computed as linear combinations of these two functions.

3 PRELIMINARY RESULTS

The prototype system has been tested on historical data sets. Fig. 2 shows the 700 hPa wind field from a height-wind analysis for one case, hurricane Opal at 00 UTC 5 October 1995, using the ETA model 12-hour forecast as a first guess. The corresponding analysis increments (and observation residuals) are shown in Fig. 3, indicating that the analysis weakened the circulation and moved it to the east relative to the first guess. Of particular interest are the negative height increments over Tallahassee and Tampa, which induce a cyclonic circulation in the

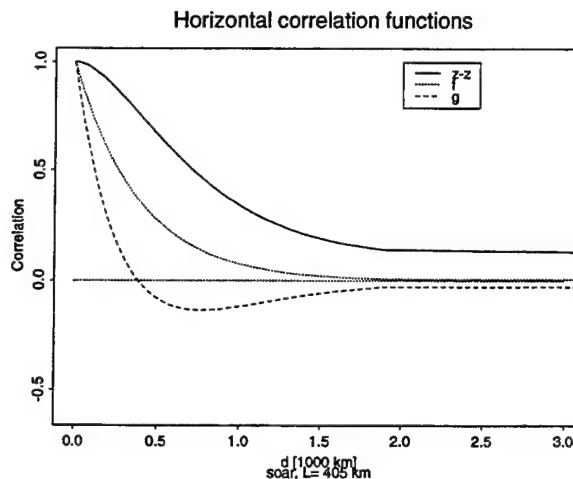


Figure 1: Horizontal height error correlation functions for global model backgrounds (see text).

wind increments over northeast Florida. This feature is completely absent if height observations are not used in the analysis (Fig. 4): the double-vortex structure of the wind increments in the multivariate analysis is replaced by a single large anticyclonic circulation in the winds-only case.

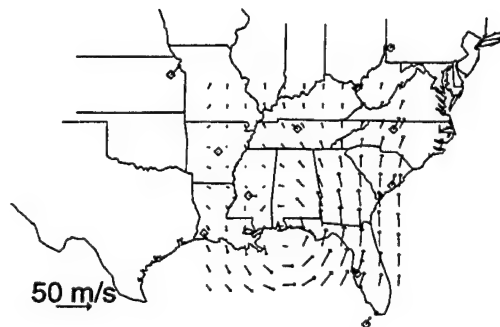


Figure 2: Wind field from a height-wind analysis at 700 hPa for hurricane Opal, using the 12-hour ETA model forecast as a first guess. Raobs used in the analysis are plotted as vectors originating from diamond symbols.

4 FUTURE PLANS

Capabilities that will be added to the existing prototype include:

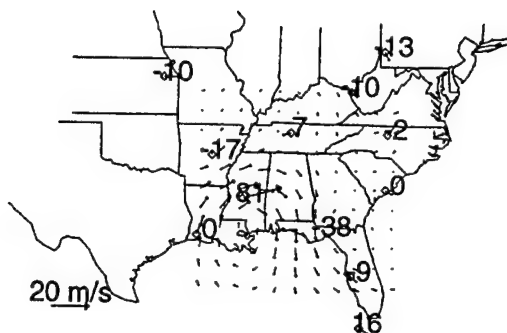


Figure 3: Wind analysis increments at 700 hPa for hurricane Opal, from a multivariate height-wind analysis. Also shown are observation increments for height (values in m) and winds (vectors).

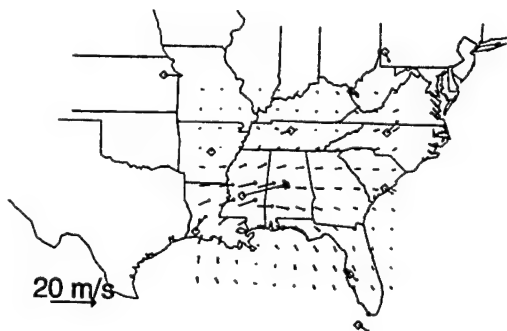


Figure 4: Wind increments at 700 hPa for hurricane Opal, from a winds-only analysis.

- an OI "buddy check" procedure in which each observation is compared to an analyzed value derived from surrounding observations
- a point-by-point method for data selection based on stepwise regression (Jennrich, 1977), in which observations are added (or deleted) based on the correlations with the analysis grid points and the already selected observations.

In addition, key system components (data selection, computations of correlations, normal equations solution) will be refined for optimizing performance and execution speed.

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B Early Prototype User's Manual for Testing at the Combat Weather Facility

User's Manual prepared for the real-data tests of TAP by Air Weather Service personnel at the Combat Weather Facility in Hurlburt Field, Florida.

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1 Introduction

The Theater Analysis Procedures (TAP) are being developed to provide a meteorological analysis capability that will reside on a computer workstation. The prototype system is being tested early on in the development cycle by Air Weather Service (AWS) personnel at the Combat Weather Facility (CWF). The testing serves the dual purpose of familiarizing AWS with TAP capabilities, and providing feedback to the TAP developers about strengths and weaknesses of the system.

2 Scope

2.1 Identification

This document is the User's Guide for the early prototype testing of the TAP at the Combat Weather Facility (CWF). It applies to the interim version of TAP after 2 of 3 years of the basic TAP development effort. Refer to section 2.3 for a reader's guide.

2.2 System overview

2.2.1 Objectives of the TAP Project

The TAP project primary objective is to develop robust analysis procedures to support the tactical user. These analysis procedures provide stable meteorological products for end users.

TAP is modular, and capable of utilizing a variety of background and data sources. This capability allows TAP to adapt to different theater meteorological support systems (TMSSs), run on different platforms and satisfy different user requirements. TAP is configurable to a range of requirements, from first-in stand-alone capability to full Theater Weather Central (TWC) support.

2.2.2 Major Functions of TAP

The function of TAP is to use the optimal interpolation technique to combine background (i.e. *a priori*) information with observations of diverse type, quality, and density to produce analyses of meteorological fields. The TAP analysis configurations are optimized to initialize NWP models and to provide input for TDAs.

2.2.3 Performance Issues

TAP is required execute in minutes on a modest workstation. TAP is required be robust. Note that the early prototype version will not satisfy all the performance requirements because less efficient, but more general and robust methods are used in parts of the system. Performance bottlenecks will be identified and replaced by faster code in the remainder of the TAP development.

2.2.4 Management and Technical Constraints

TAP is state of the art, but not experimental. TAP is designed to work every time. In measuring the quality of TAP, robustness of the system is weighted heavily.

2.3 Document overview

This document gives a brief overall description of the TAP project, provides instructions for installing and running the TAP system, and describes the test cases provided for this early prototype test at the Combat Weather Facility (CWF).

At a minimum, test personnel should read Sections 5.1 and 5.2 for basic operation of the system. For interpretation and evaluation of the test results, test personnel may refer to Section 6. For troubleshooting, test and support personnel may refer to Section 5.5.

3 Referenced documents

For more detailed TAP documentation, see also the System and Interface requirements specifications and design documents (document `srs`, document `sdd`, document `irs`, and document `idd`). The plan for testing at the CWF is described in a memorandum by the Phillips Laboratory dated 15 March 1996 (revised 30 April 1996). This memorandum contains a description of the test objectives and schedule, which is not repeated here. Detailed test evaluation criteria are provided in the form of a questionnaire which is distributed to all test personnel.

4 Installing TAP

4.1 Required system software

The following system software is assumed to be preinstalled on the host system:

- Solaris 2.4 operating system
- Sun Fortran 77 compiler
- Sun C compiler.

4.2 Installing supporting software

4.2.1 Splus

The TAP system makes extensive use of the Splus software package. It is a proprietary software package for interactive data analysis and display that is provided with its own storage medium and installation instructions. The location of the Splus software (both the location of the Splus Home directory and the directory of the executable Splus script) must be recorded for later use in the TAP installation.

4.2.2 Netscape server and browser

The graphical user interface of TAP makes use of the Netscape software packages for running an http (HyperText Transfer Protocol) server and browser. It is a proprietary software package that is provided with its own storage medium and installation instructions. For purposes of the TAP demonstration, a copy of the needed software has been placed on the tar tape along with the other binaries (see below). The browser is automatically installed by performing the tar command described below. Before running the installation script for the server (`server/httpd/install/ns-setup`), the directory containing the browser (or a link to it) must be included in the PATH. The location of the Netscape browser executable must be recorded for later use in the TAP installation. The Netscape server must be configured to enable execution of CGI (Common Gateway Interface) scripts by editing of the files `config/magnus.conf` and `config/obj.conf` files (either manually or with the supplied Server Manager). The host name of the server machine, and the http address of the directory containing the cgi scripts, must be recorded for later use in the installation. Some system files may need to be edited for proper operation of the server.

4.2.3 Others

All other software packages have been assembled onto a tar tape and can be directly restored from tape to disk. For the basic TAP system, they are: GNU Make and related utilities; Ghostview, xv, and related utilities; perl; LAPACK and BLAS source code and binary files. To support the generation of postscript documents from the \LaTeX source files, the \LaTeX package is also included in the basic package of supporting software. The location of the binaries must be noted for later use in the TAP installation.

The supporting software, including Netscape, are installed by a simple tar command. For example, if the software is to be stored in directory `/users/cwf/tap.demo/`, then the required Unix commands are

```
cd /users/cwf/  
mkdir tap.demo  
cd tap.demo  
tar -xvf /dev/rmt1 |& tee tar.out1
```

where `/dev/rmt1` denotes the tape drive on which the tar tape is mounted. Upon completion of this command, several new directories are created, which contain all the supporting software. A listing of all the files is contained in file `tar.out1`.

Not included in the basic package are utilities and programs that are only needed for the software development environment: RCS for version control, Gnu Emacs for editing of files and system-level interactive use of the TAP software.

4.3 Installing the TAP software

The TAP software and ancillary datasets are all stored together under the `TAPHOME` directory. For the purpose of the early prototype test, since both the machine used during TAP

development and for the early prototype are Sun workstations, binary versions of the TAP code and data sets can be directly installed on the host system. The entire directory tree structure is stored on a tar tape, and installation only requires transfer from the tar tape onto the appropriate directory on the disk of the host system. For example, if the desired disk location is `/users/cwf/tap.demo/`, then the required Unix commands are

```
cd /users/cwf/tap.demo
tar -xvf /dev/rmt1 TAPHOME |& tee tar.out2
```

where again `/dev/rmt1` denotes the tape drive on which the tar tape is mounted. Upon completion of this command, a new directory `TAPHOME` is created, which contains all the TAP software and ancillary data. A listing of all the files is contained in file `tar.out2`.

After transfer of the data to disk, some editing of files is required to change path names of certain system and supporting software. A cshell script (`install.csh`) in the `TAPHOME` directory is provided for this purpose. The script creates and executes a file of editor commands (for the UNIX `sed` editor), based on user responses to queries for locations of the various software packages and system binaries. Default values are provided for most of these. Refer to file `TAPHOME/README` for up-to-date instructions.

As a final step in the installation, files with filename extension `cgi` in directory `TAPHOME/html` must be copied to the location designated for CGI scripts during the Netscape server installation.

4.4 Adding or removing TAP users

TAP is set up to support multiple users. Separate disk areas are provided for each user for storage of output and intermediate files. Adding a user, (for example: `bob`) simply requires the addition of subdirectories by the commands:

```
mkdir $TAPHOME/users/bob ; mkdir $TAPHOME/users/bob/.Data
```

Conversely, removing this user is accomplished by

```
"rm" -fr $TAPHOME/users/bob
```

For the usual, single-user mode of operation, the user name `tap` is preinstalled on the system.

5 Running TAP

Two ways of running the TAP system are provided for the early prototype testing at CWF: cshell scripts which are invoked by the user from the system prompt after login, and a graphical user interface which requires running a Web server (Netscape server) on the host system and a Web browser (such as Mosaic or Netscape) by the user. It is anticipated that the graphical user interface will be the preferred way of running TAP, but the cshell scripts are provided as a backup and alternative for users with more Unix experience.

5.1 Required initializations for the Unix session

Before invoking TAP through either the graphical or cshell user interface, the environment variable `TAPHOME` must be set to the location of the tap software, e.g. in the above example it would be

```
setenv TAPHOME /users/cwf/tap.demo/TAPHOME
```

Further environment variables and command aliases are then set by issuing the command

```
source $TAPHOME/setenv.csh
```

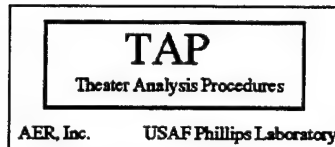
Note to system administrator: Both of these commands could be included in the user's `.cshrc` file, so that they will be executed automatically upon login.

A simple help command (`tap.help`) is provided that lists all available tap commands and the user's TAP configuration. It is described in more detail in Section 5.3.

5.2 The graphical user interface

The graphical user interface is invoked by the command `tap.web &`. It does not matter from what directory this command is invoked. This will start the Web browser and open the TAP main-menu page (see Figure 1 for an approximate rendition of the display as seen on a computer terminal).

When displayed on a computer terminal, "hyperlinks" to other TAP pages are specially marked text (usually underlined); moving the cursor to such a hyperlink and clicking the left mouse button will display the referenced page. The main-menu page can be displayed again by clicking on the main-menu links in the other TAP pages, or by using the "Back" command of the Web browser (using the "Go" pull-down menu in the case of Netscape version 2). Both the TAP overview and documentation pages provide background information on TAP and require no further explanation here. The View gif images of NWS products page is a link to a directory containing gif images in several subdirectories. Clicking on this link will display a listing of that directory. From a directory listing, one can view listings of subdirectories or images of gif files by clicking on the appropriate directory or file name. The date and time and type of plot are apparent from the directory and file names. The remaining pages (`execute`, `plot`, `status check`, and `remove`) are hypertext "forms", containing a number of input fields that are either entered from the keyboard, or selected by mouse clicks on specially marked "button" icons. Once filled out with all the required inputs, they are submitted by clicking on a button at the bottom of the page which is labeled with the action to be performed. Submitting the form initiates processing, and causes a new page to be displayed with output generated from the process. These pages are described in more detail below.



Caution: TAP is under construction.
Your help is appreciated. Please send e-mail to the address below.

TAP main menu

- TAP overview
- TAP documentation
- Check status of TAP analysis jobs
- Execute TAP
- Plot a TAP map
- View gif images of NWS products
- Remove TAP output from user directory

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Work in Progress. All Rights Reserved.
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rhoffman@aer.com*

This is Theater Analysis Procedures (TAP) html documentation.

The TAP project (AER P584) is funded by the USAF (F19628-94-C-0027).

AER, Inc. intends to retain patent rights to certain aspects of the TAP algorithms under FAR 52.227-11.

Revision control: \$Id: main.menu.html,v 1.4 1996/04/29 20:47:21 trn Exp trn \$

Figure 1: TAP Main menu page

5.2.1 Status check page

Before executing a TAP analysis, one must make sure there are no other TAP analysis jobs running. Before plotting results from a TAP analysis, one needs to know the name given to the analysis run, and make sure it has completed. The Status check page (see Figure 2) provides a convenient way of accomplishing this.

Check on TAP cases

* Analysis Name:

- There are 2 Options:

- (1): list names and brief description of all cases: Leave Analysis Name blank
- (2): provide a full list for a single case: Analysis name must be specified

* Analysis owner:

Figure 2: Required inputs for the TAP status check menu page. Analysis Name and Owner are text fields to be entered.

Submitting this form will launch a unix command to examine the TAP user directory for analysis output files. The output will be displayed to the screen.

Using an empty (blank) field for Analysis Name will produce a list of all analysis jobs and indicate whether they have finished or are still running. Also listed for each analysis job is its timestamp file, which contains information on the start and end time, and the levels and variable codes used for the analysis. Specifying an analysis name will display, in addition, the size of all data files for that analysis, and the contents of the log file. This display is useful for debugging purposes, but should not usually be required. Interpretation of the log file should be referred to the software programmer.

The TAP user name (also referred to as "analysis owner") identifies a disk space unique to that user. The only valid user names are those for which directories have been established at the time of installation. The default value ("tap") is the name reserved for the usual, single-user mode of operation of TAP. The TAP user name has no connection to the Unix login or user name.

5.2.2 Execute page

This link is selected to execute TAP and produce an analysis. The required user inputs are shown in Figure 3.

Submitting this form will launch an analysis job. The input specifications will be listed to the screen immediately. Results may be plotted upon completion of the job (see Section 5.2.3). The status of TAP analysis jobs may be checked using the Status check page (see 5.2.1) to make sure no other jobs are running, and to check on the status of the current job.

Execute TAP

Set the following parameters to specify a TAP analysis.

- * Data source:
 - March 95, N.E. US (12 UTC 6 March 1995)
 - March 95, S.E. US (12 UTC 6 March 1995)
 - Opal, N.E. US (00 UTC 5 October 1995)
 - Opal, S.E. US (00 UTC 5 October 1995)
- * Domain:
 - Large analysis domain using 150 km resolution
 - Small analysis domain in center using 75 km resolution
 - Column at domain center (with 75 km effective resolution)
- * Analysis scheme:
 - Height/wind analysis (upper air). codes= (7,33,34)
 - Height analysis (upper air). code= 7
 - Wind analysis (upper air). codes= (33,34)
 - Temperature analysis (upper air). code= 11
 - RH analysis (upper air). code= 52
 - Surface Temperature analysis (2d). code= 11
- * Background type:
 - Climatology
 - 12-hour ETA model forecast
- * Analysis name:
- * Analysis owner:

Figure 3: Required inputs for the TAP execute menu page. Analysis name and owner are text fields to be entered, all others are choices that are selected by clicking a button icon next to the desired value.

Warning: No other analysis jobs should be running at this time in the TAP user directory.

For purposes of the prototype tests, TAP is restricted to running a number of canned cases over prespecified regions and analysis domains. The Data Source selection identifies the case (date and time) and geographic region, and the analysis domain one of the three available analysis grid options. The cases and grid options are described in more detail in Section 6. The analysis scheme selects the type of analysis to be produced. All upper air analyses are at a preselected set of pressure levels (1000 mb; 925 mb; 850 mb; 700mb; 500 mb; 400 mb; 300mb; 250 mb; 200 mb; 150 mb; 100 mb).

The name of the analysis must be a legal UNIX file name and a legal Splus variable name. This is always guaranteed if it begins with a letter and contains only alphanumeric characters. It is important to make a note of the name of the analysis, because this name is needed to generate plots.

Warning: Reusing a name will overwrite a pre-existing analysis.

The Analysis owner must be a valid TAP user name (see Section 5.2.1).

5.2.3 Plot page

Upon completion of the TAP job, results may be plotted using the plot page shown in Figure 4. Plots will be plots of one or more variables at the analysis grid points, at one of the analysis levels, over a map background of the analysis domain. Values of observations used in the analysis may optionally be overlayed over the plot.

Submitting this form will launch a job that will create graphical output (in postscript format) in the specified file (default: `tap.ps`) in the user's directory. A listing of specified plot parameters is echoed to the screen. Upon completion of the plot job, a postscript viewer (ghostview) is invoked to display the graphical output to the screen. The ghostview window contains pull down menus for printing a hard-copy of the output, saving it to a file with a different name, magnification/reduction, and numerous other display options.

The name of the analysis must be specified. It must be the name of a previously completed analysis job (see Sections 5.2.2 and 5.2.1).

The analysis owner must be a valid TAP user name, and it must be the owner of the analysis to be plotted.

For variables other than wind vectors, contour plots are drawn if the analysis name is an analysis over the small or large domain. If the analysis is for a single column, the value is printed at the analysis point location. Other display options (e.g., for vertical profiles or cross sections) may be added at a later date. The code numbers displayed with the choice of variables refer to the code numbers assigned to each variable within TAP. These code numbers are also displayed on the title of the plots. Selecting either a variable or a level that is not present in an analysis will produce a message (in the postscript output file and the display generated from it) listing the available levels and/or variables.

The plot type options identify what type of values are displayed: either analyzed values, background values (interpolated to the analysis locations from either the forecast or climatology first guess), or increments (the difference between the first guess and the analysis values). For increment plots, observation plots will be those of observation increments (i.e.,

Plot a TAP map

Set the following parameters to specify a TAP map.

* Analysis name:

* Analysis owner:

* Variable:

- Geopotential height (Z) [gpm]. Code=7
- Wind vectors [m/s]. Code=33 34
- Geopotential height (Z) [gpm] plus Wind vectors (u,v) [m/s]. Code=7 33 34
- Temperature (T) [K]. Code=11
- Relative humidity (RH) [%]. Code=52

* Level:

Surface; 1000 mb; 925 mb; 850 mb; 700mb; 500 mb; 400 mb; 300mb;
250 mb; 200 mb; 150 mb; 100 mb

* Plot type:

Analysis; Background; Increments

* Overlay observation values:

True; False

* Postscript file name:

Figure 4: Required inputs for the TAP plot menu page. Analysis name and owner, and the postscript file name, are text fields to be entered, all others are choices that are selected by clicking a button icon next to the desired value.

the difference between the observed value, and the background value interpolated to the observation location).

5.2.4 Remove TAP output page

This page provides a way to remove output files from TAP analysis jobs from a TAP user directory. Care must be taken when using this page to specify the correct Analysis name(s) and owner. Should this page be selected by mistake, one can always “back out” by clicking on the main menu link or using the Netscape “back” feature: Files will not be deleted until the button labeled “REMOVE cases” is clicked.

The inputs required by this page (Figure 5) are quite similar to those of the status check (Section 5.2.1). Note, however, that the default field for the analysis name is chosen such that it will not match any likely case names, to avoid accidental deletion of cases. If all cases are to be deleted, a blank input string has to be entered into the input field.

Remove TAP cases

- * Analysis Name:
 - There are 2 Options:
 - (1): remove all cases: Fill in a blank for the Analysis Name
 - (2): remove one or more case(s): Analysis name(s) must be specified
- * Analysis owner:

Figure 5: Required inputs for the TAP remove menu page. Analysis name and owner are text fields to be entered.

Submitting this form will launch a UNIX job that will remove all output files from the specified analysis name(s) in the user’s directory. Output from the unix command is echoed to the screen.

5.3 The csh user interface

The csh user interface is provided as a fallback option, should the graphical user interface be unavailable. It also provides the option for more experienced Unix and TAP users to automate some TAP functions.

The csh user interface is started with the `tap.csh` command (see Section 5.3.2). A basic help command (`tap.help`) may be issued before starting the csh user interface.

5.3.1 The `tap.help` command

This command is invoked by entering `tap.help`. It produces output to “standard output” (normally the screen), containing a list of all TAP commands, and current settings of TAP-

related environment variables and command "aliases". A sample output is shown in Figures 6 and 7.

Theater Analysis Procedures (TAP) help:

Required initialization:

need to "setenv TAPHOME ..." and "source \$TAPHOME/setenv.csh"

Start TAP graphical user interface:

tap.web

Start csh user interface:

tap.csh - this changes your working directory

Also needed when changing the TAP user name

csh user interface commands:

tap.execute - execute a TAP analysis run

(invoke without arguments for help)

tap.map-plot - produce a plot from results of a TAP analysis run

(invoke without arguments for help)

tap.check - list all analysis names

(optional arguments: produce a full list for those analysis names)

tap.remove - Remove all output files for each analysis name

(optional arguments: only remove those analysis names)

Figure 6: Sample output from the tap.help command – Part A: List of commands.

5.3.2 Starting the csh user interface

This command is invoked by issuing `tap.csh`. It will prompt for input from "standard input" (normally the keyboard), asking for the TAP user name. It will then change the current working directory to that user's TAP directory. Specifying an invalid TAP user name will result in repeated prompts for valid user names. This can be stopped by entering "quit" instead of a user name. A sample session is shown in Figure 8.

5.3.3 Status check of TAP analysis jobs

Command `tap.check` is provided for checking on the status of TAP analysis jobs in the user's directory. When invoked without command line arguments, it will list all analysis jobs in the user's directory, indicate whether they are still running or have completed, and list the contents of their timestamp files. (The command keys on the presence of the timestamp, which are files with the filenames extension `.timestamp`, and which contain information on the hostname, start and end date and times, and variables and levels analyzed, for an analysis

Your present TAP setup is:

your directory:/users/cwf/tap.demo/TAPHOME/users/tap

TAP-related environment variables:

```
PWD=/users/cwf/tap.demo/TAPHOME/users/tap
TAPgrib=/users/cwf/tap.demo/TAPHOME/DATA/GRIB
TAPfixed=/users/cwf/tap.demo/TAPHOME/splus/.Fixed
TAPaims=/users/cwf/tap.demo/TAPHOME/DATA/AIMS
TAPSTATS=/users/cwf/tap.demo/TAPHOME/error_stats/baseline
TAPHOME=/users/cwf/tap.demo/TAPHOME
TAPFORT=/users/cwf/tap.demo/TAPHOME/fortran
TAPC=/users/cwf/tap.demo/TAPHOME/C
OORTHOME=/users/cwf/tap.demo/TAPHOME/oort/fmtfilt
```

TAP-related aliases:

```
tap.check csh -f $TAPHOME/splus/check-cases.csh !* | \
  sed -e "s/<[/]*strong>//g" | sed -e "s/<[/]*h[1-9]>//g"
tap.csh source $TAPHOME/splus/tap.csh
tap.execute csh -f $TAPHOME/splus/tap.execute.csh
tap.help source $TAPHOME/splus/tap.help.csh
tap.map-plot csh -f $TAPHOME/splus/tap.map-plot.csh
tap.remove
setenv prompt $prompt ; csh $TAPHOME/splus/remove-cases.csh !* ; unsetenv prompt
tap.web netscape $TAPHOME/html/main.menu.html
```

Figure 7: Sample output from the tap.help command – Part B: TAP environment.


```

Starting the TAP csh user interface:
Enter your TAP user name (usually "tap"; "quit" if you want to quit now): tan
This is an invalid TAP user id: tan
Please try again
Enter your TAP user name (usually "tap"; "quit" if you want to quit now): tap
/users/cwf/tap.demo/TAPHOME/users/tap

Your current directory is now:/users/cwf/tap.demo/TAPHOME/users/tap
You need to repeat "tap.csh" to change TAP user names or
if you issue any "cd" commands during your csh session

Issue tap.help for basic TAP help

```

Figure 8: Sample session of the tap.csh command.

job.) When invoked with optional command line argument(s), the examination is restricted to the analysis names specified on the command line (this corresponds to the Analysis Name input field in Figure 2). In this case `tap.check` provides a full listing of diagnostic information for each of the analysis names (it should thus be invoked in combination with the Unix `more` command or output redirection). See Section 5.2.1 for a discussion of the output from this command.

5.3.4 Execute TAP analysis jobs

The `tap.execute` command launches an analysis job. It differs from the corresponding graphical user interface command (Section 5.2.2) in two important respects: the analysis name is constructed internally and not specified by the user; more than one analysis job can be spawned by specifying multiple options for any one of the four possible input parameters. To avoid simultaneous execution of multiple analysis jobs, the command script waits for the completion of each job before starting the next job (or exiting the script). Thus, it is best to run this command in the background (and redirect its output to a file for later examination). A typical sequence of commands is to invoke the command without any arguments to display its help message (Figure 9), and then to invoke it again with command line arguments, output redirection, and in the background:

```

tap.execute
tap.execute Mar95NE "( zuv rh )" large eta12 >&! test.out &

```

The command line arguments closely correspond to the choices of the TAP execute page (Section 5.2.2). In this example, two analysis jobs will be run: one is a height and wind analysis, the other a relative humidity analysis, both for the March 1995 case over the Northeast region, using the large analysis domain and the ETA 12-hour forecast as a

background field. The analysis names are constructed from the selected options. In this example, they are Mar95NE.zuv.large.eta12 and Mar95NE.rh.large.eta12.

tap.execute needs 2-4 args:

- 1: caseIds. one or more of (Mar95NE Mar95SE OpalNE OpalSE)
- 2: aschemes. one or more of (zuv z uv t rh ts)
- 3: grid.types. One or more of (column small large). Default: column
- 4: Background types. One or more of (climo eta12). Default: climo

NOTES:

- (1) if giving more than one in any of the above, need to do it in this form (using the exact same quotes and spaces): "(column small)"
- (2) run this script in the background (Put a "&" at the end of the command line) if you want to perform other tasks while tap.execute is running

Figure 9: Help message from the tap.execute command.

5.3.5 Plot a TAP plot

Tap plots are produced by the tap.map-plot command. Invoking the command without any command line arguments will display its help message (see Figure 10). The command line arguments closely correspond to the menu choices of the TAP plot page (Section 5.2.3).

5.3.6 Remove TAP output

Output files from TAP analysis jobs are removed by the tap.remove command. Invoking the command without any command line arguments will remove the output from all analysis jobs in the current directory. Optional command line arguments are names of cases to be removed. (This is analogous to the analysis name input field in Figure 5). When run in an interactive shell, this command will prompt the user for confirmation before removing any files.

5.4 TAP execution times

Table 1 lists wall clock times for the early prototype TAP. These estimates were obtained on a dedicated Sun workstation, using the test cases of the CWF test. This table is also accessible from the graphical user interface (the execution and plotting pages both provide links to this table).

5.5 Troubleshooting and error recovery

In the following, some possible error conditions and their likely causes and remedies are listed. This section is geared toward the graphical user interface; since the underlying problems will

tap.map-plot needs 1-5 args:

- 1: Analysis name. You must know this name to plot it.
- 2: Variable. One of: "c(7,33,34)", 7, "c(33,34)", 11, 52
corresponding to: z + (u,v) , z, (u,v) , t , rh
Default: "c(7,33,34)"
- 3: Level. Pressure in mb, or "0" for surface plots
Default: "500"
- 4: Type of plot. One of "anv" (analysis values);
"bgv" (background values); "inc" (Increments)
Default: "anv"
- 5: Flag ("T" for yes, "F" for no) for overlaying observations
Default: "T"
- 6: Postscript file name
Default: "tap.ps"

Figure 10: Help message for the tap.map-plot command.

Generating a plot: less than 2 minutes

Generating an analysis:

| Analysis type | large or small grid | column at domain center |
|--------------------------|---------------------|-------------------------|
| Height and winds | 30 minutes | 6 minutes |
| Winds | 20 minutes | 5 minutes |
| Scalar (Temperature, RH) | 14 minutes | 5 minutes |
| Surface temperature | 7-10 minutes | 2 minutes |

Table 1: TAP execution time estimates

be the same in most cases for both user interfaces, it can also be used for the csh user interface. In case these suggestions do not solve the problem, help should be sought from the TAP developers/software support.

Screen display shows the line "Can't cd to ..." on top: this is caused by an invalid Analysis Owner name. Correct the form and resubmit.

Ghostview produces an error message: "Warning: failed to allocate ... RGB cube."
This occurs when other applications running on the workstation (such as Netscape) have already used up too many colors from the workstation color table. This may affect the colors displayed to the screen, but the message can otherwise be ignored.

Screen display shows TAP request is submitted, but nothing happens: there are several possible reasons.

1. The plotting job may still be executing. Plots should be displayed on the screen after a minute or two (see Table 1).
2. The analysis may still be executing. Use the Status check page to check for this. Execution times for analyses range from 2 - 30 minutes (see Table 1).
3. An invalid TAP user name is used. Make sure to check the top of the page shown after you submit the form for the "Can't cd to ..." error message, and correct the user name if needed.
4. The plotting job may have failed because an invalid analysis name was specified. Double-check your analysis name (use the Status check page if you forgot the name of your analysis).
5. The plotting job may have completed, but the output could not be displayed. If running Netscape on a different machine than the server, make sure to use the xhost command to add the server to your access list. If running the csh user interface, make sure the DISPLAY environment variable is set correctly. If all else fails, examine the user's directory for the presence of the postscript file, and examine the plotting job log file.
6. The plotting job may have failed because the analysis output is corrupted. See the discussion of analysis errors below.

Status check lists the Unix command, but produces no output: this is not an error, but reflects the fact that no analyses were found. Make sure you specified the correct Analysis owner and name.

Status check does not show the analysis: (even though the screen display shows the TAP Splus tap.execute request is submitted) There is a short delay between starting the Splus job and the creation of the timestamp file. If status check is used too soon after the submission of the request, the timestamp file may not be created yet. Another possibility is that the Analysis owner and name were incorrectly specified.

Status check gives a warning message about a job running in BATCH: This means that there apparently is an analysis job running in the user directory which was started from the csh user interface. This is detected by the presence of a file (BATCH.RUNNING) in the user's directory. No analysis jobs should be started until this jobs has completed or has been aborted.

How do I kill an analysis job? This requires knowledge of the UNIX `ps`, `kill` commands. From the UNIX command prompt, the processes launched by the execute page (or the `tap.execute` command) must be located and killed. They can be identified by their process IDs, and/or their command names. Both the graphical user interface and the `tap.execute` script use the `Splus BATCH` command, which spawns an `Splus` process (this will appear as `Sqpe` in the listing produced by `ps`). As an alternative to kill, it is also possible to repeatedly remove (`tap.remove`) all output files from the running analysis job - this will lead to internal errors in the analysis job and its abnormal termination; however, note that the job may still be running in this case even though its `.timestamp` file no longer exists, in which case the Status check page will incorrectly indicate that there are no more jobs running.

How do I remove output files from old or killed analysis jobs? This can be done from the graphical (Section 5.2.4) and the csh user interface (`tap.remove`).

Causes of analysis job errors : Aside from internal execution errors, which should be referred to the TAP developers/software support, analysis jobs may terminate abnormally because of system-level problems:

1. Running out of memory. This will be indicated by an error message in the `Splus` job log file (produced by the Status check page): "Cannot allocate requested dynamic memory ...". Make sure no other memory intensive jobs are running on the system at the same time as the TAP analysis job. Make sure enough swap space is allocated to the system.
2. Running out of disk space. Use the `tap.remove` command to clean out user directories as needed.

6 Test Description

For purposes of the prototype tests, TAP is restricted to running a number of canned cases over prespecified regions and analysis domains. These have been chosen to present a typical sample of options of the envisioned operational TAP system. At present, the data sources are restricted to radiosondes for the upper air analyses, and surface station reports (SYNOP, Service A, and ship/buoy reports) for the surface analyses.

6.1 Analysis domains

A set of three nested analysis domains is used in two separate geographic regions, one over the Northeast and one over the Southeast United States. The outermost, large grid domain

covers a region of approximately 1500 km on a side. Centered inside the outer region is the small domain, covering a region of approximately 750 km on a side. Both grids consist of 11 by 11 gridpoints. Finally, the column domain represents the grid column at the center grid point of the small analysis domain. Over the Northeast region, a polar stereographic projection basemap is used (with a reference longitude at 80° W), and the analysis domains are centered over southeast Pennsylvania (see Figure 11). Over the Southeast region, a Mercator projection basemap is used, and analysis domains are centered over Alabama (see Figure 12). The analysis grids were chosen to contain both land areas with dense data coverage and data sparse areas over water.

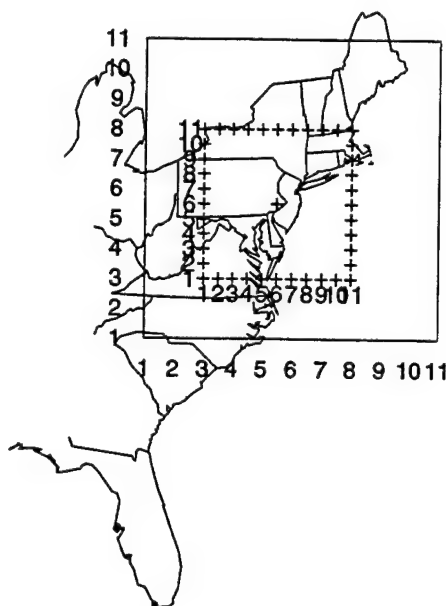


Figure 11: The three analysis domains over the Northeast region.

6.2 Test cases

6.2.1 March 1995 case

The analyses for this case are for 12 UTC 6 March 1995. The synoptic situation on that day was characterized by an upper-level shortwave passing through the Northeastern United States and Canada, embedded in a southwesterly upper-level flow. At the surface, this was accompanied by a weak low (central pressure around 1016 hPa) and rain over the Northeastern United States, snow over parts of Quebec and the Canadian Maritimes. This case represents a typical moderate to weak winter/early spring storm over the Northeastern United States. An example TAP 850 mb height and wind analysis is shown in Figure 13. Over the southeast region, the situation is dominated by a ridge (see Figure 14).

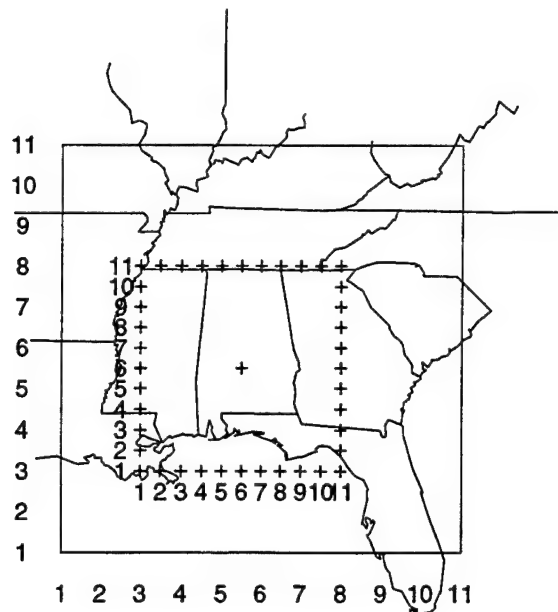
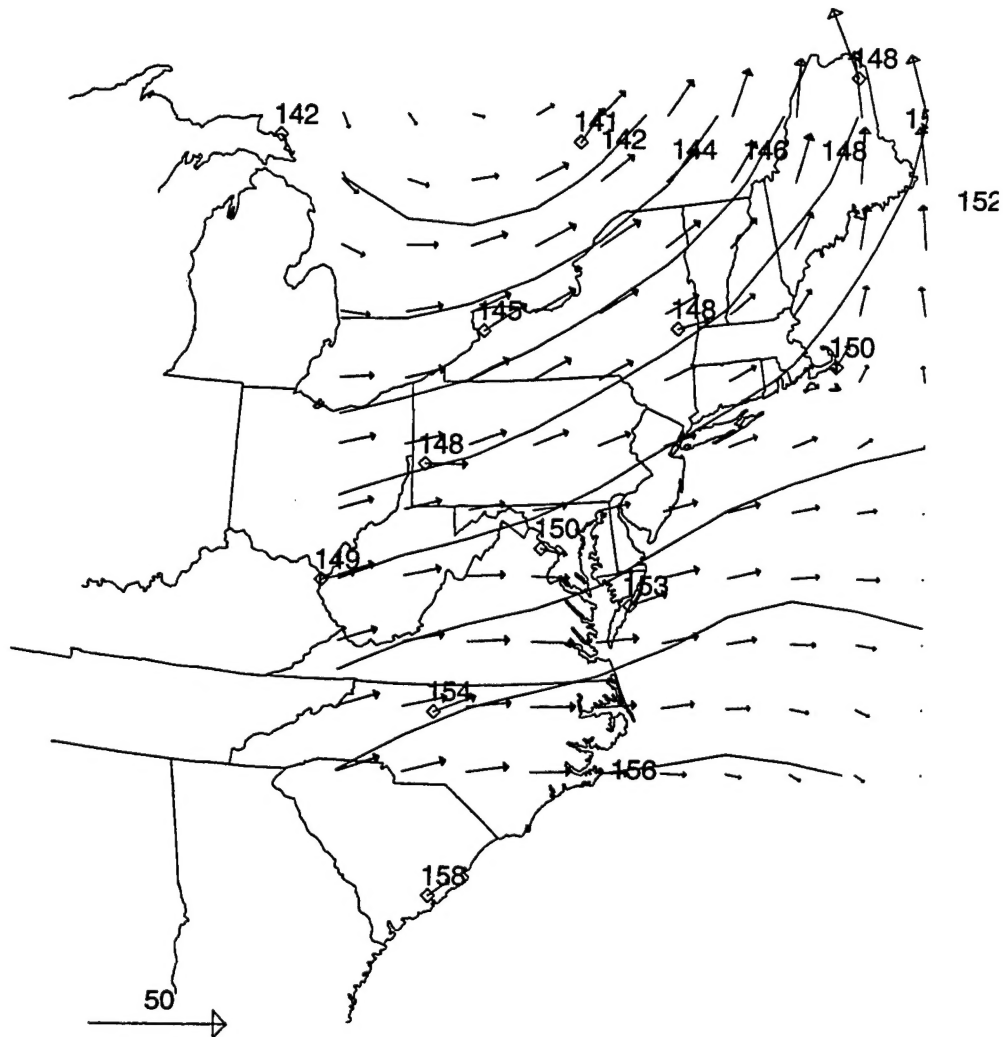


Figure 12: The three analysis domains over the Southeast region.

6.2.2 Opal (October 1995) case

The analyses for this case are for 00 UTC 5 October 1995, approximately 1 hour after Hurricane Opal made landfall in the Florida panhandle (Figure 15). Opal was a strong hurricane, causing over \$3 billions of damage and over 20 deaths. It thus represents an extreme weather event. Unfortunately, because of the extreme weather conditions, key radiosonde reports are missing for this case at some or all of the levels. The results of the analysis thus depend strongly on whether the ETA 12-hour forecast or climatology is being used as a background field. In particular, if the column analysis domain is chosen over the Southeast region, there will be no radiosonde reports in the data window surrounding the analysis point at some of the level. The analysis value in this case is simply equal to the background value. Over the Northeast region, there are weak shortwave features embedded in a generally southwesterly flow (Figure 16).

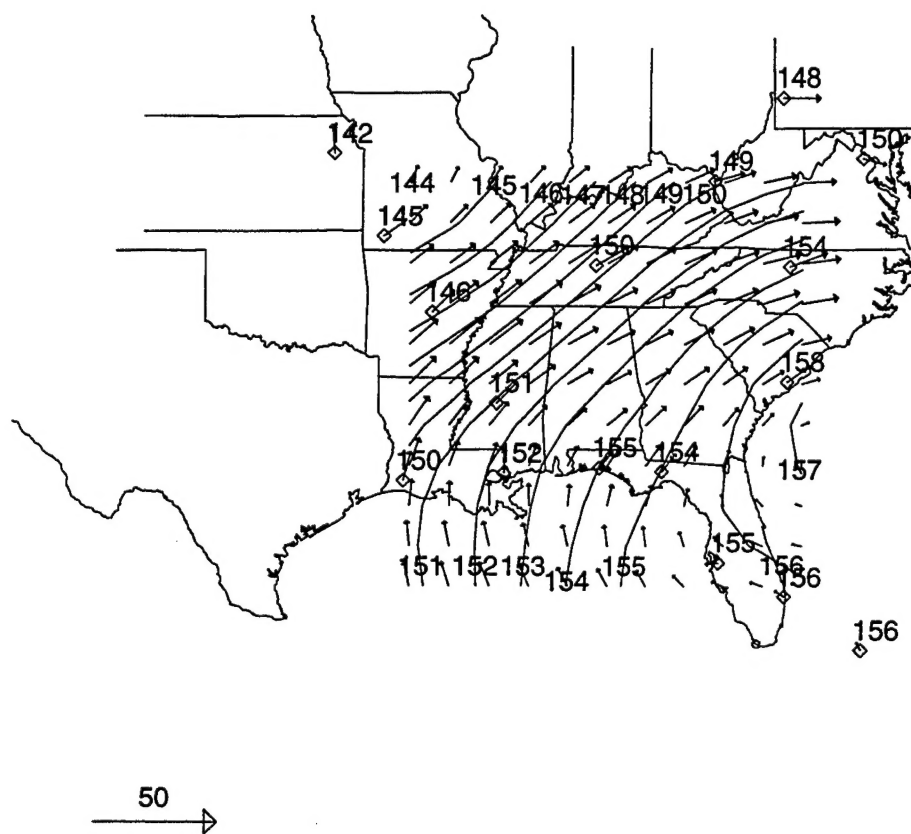
Mar95NE.zuv.large.eta12 anv Level= 850 Var= 7 33 34



Date/Time: 19950306 120000 Var= 7 scaled by 10

Figure 13: TAP analysis for height and winds at 850 mb over the Northeast region for the March 1995 case.

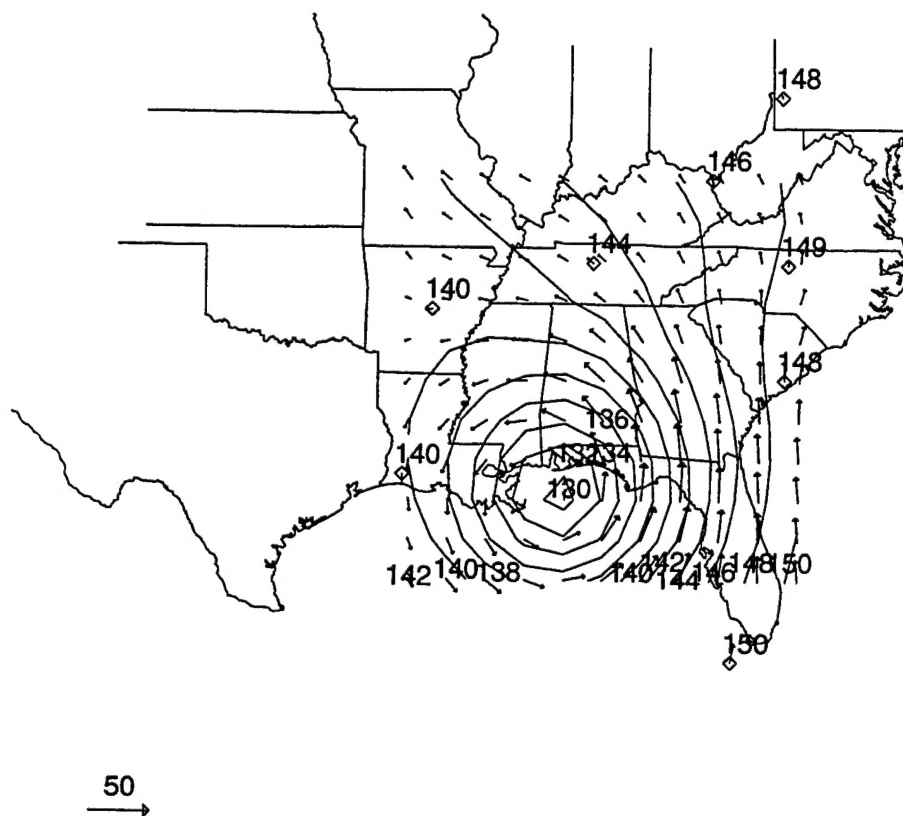
Mar95SE.zuv.large.eta12 anv Level= 850 Var= 7 33 34



Date/Time: 19950306 120000 Var= 7 scaled by 10

Figure 14: TAP analysis for height and winds at 850 mb over the Southeast region for the March 1995 case.

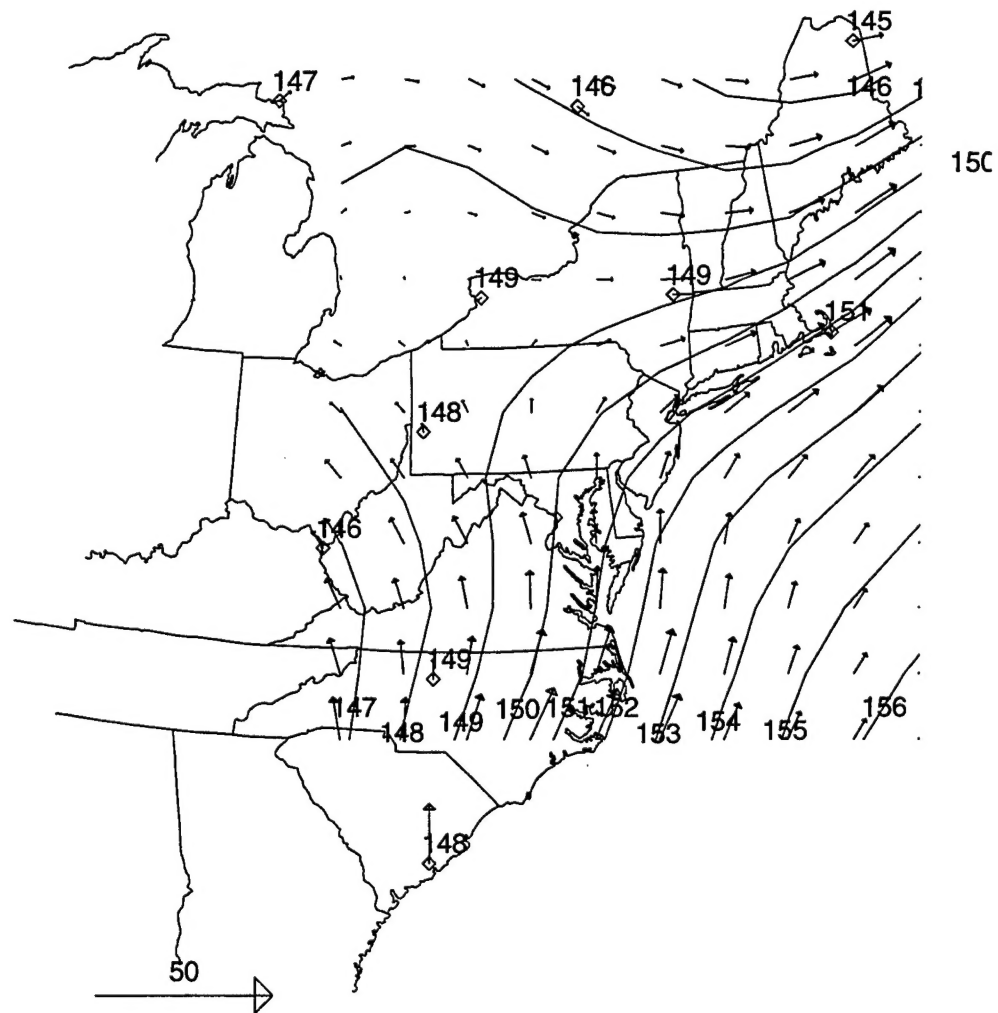
OpalSE.zuv.large.eta12 anv Level= 850 Var= 7 33 34



Date/Time: 19951005 0 Var= 7 scaled by 10

Figure 15: TAP analysis for height and winds at 850 mb over the Southeast region for the Opal case.

OpalNE.zuv.large.eta12 anv Level= 850 Var= 7 33 34



Date/Time: 19951005 0 Var= 7 scaled by 10

Figure 16: TAP analysis for height and winds at 850 mb over the Northeast region for the Opal case.